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The Electronic Health Record's Impact on Labor and Delivery Nurses' Cognitive Work

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The Electronic Health Record's Impact on Labor and Delivery Nurses' Cognitive Work

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Dedication and Acknowledgements

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Contributions

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The Electronic Health Record's Impact on Labor and Delivery Nurses' Cognitive Work

Kirsten Wisner

Abstract

Background and objective: Despite recognition that electronic health record (EHR) use has introduced cognitive challenges for clinicians, few studies have evaluated its impact on the cognitive dimension of nurses' work. Labor and delivery nurses may encounter unique challenges when using the electronic health record since they also interact with an electronic fetal monitoring system. This study sought to explore labor and delivery nurses' perceptions of the EHR's impact on their cognitive work with the goal of identifying patient safety implications.

Methods and setting: This was a grounded theory study using dimensional and situational analysis. Data were interviews and observations with 21 labor nurses at two community hospitals in the Western United States.

Results: The ways that nurses configured care when using the EHR varied across participants and sites and depended on how easily they integrated it into their practice. Individual, group, and situational factors facilitated or constrained integration. This took place in a dynamic, high-acuity, specialty clinical environment while using EHRs that were not designed for pregnant women. Nurses used clinical decision support and other cognitive support features that rarely worked as intended due to the lack of EHR customization to account for pregnancy physiology and unique risk factors in the perinatal patient. Nurses viewed the quality of their relationships with patients and their families as an integral part of caring for laboring women and felt that interaction with the EHR sometimes threatened this dimension of their work.

Conclusions: When nurses were unable to integrate the EHR into care it resulted in numerous consequences that have important safety implications. Available cognitive support features lacked the specialty-specific support needed to care for laboring women and instead required nurses to track information in other ways that added to their cognitive burden and work routines. As a result, nurses and patients were not benefitting from the intended decision support and patient safety protections offered by appropriate risk assessment screens or critical alerts. These findings have important implications for the configuration and design of EHRs in perinatal settings.

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Chapter 1

Introduction to Dissertation

My interest in the electronic health record (EHR) and its impact on nurses' work originated from my own experience of the transition from a paper-based documentation system to an electronic system while working as a labor and delivery nurse in 2012. I found interaction with the EHR disruptive and destabilizing to some fundamental ways that I tracked and understood how my patient was doing. It was clear to me that my nurse and physician colleagues also struggled with incorporating the EHR into their practice and that this was a phenomenon throughout the hospital, not just in labor and delivery. Around the same time, I was working on a writing project about fetal heart monitoring documentation. When I searched the literature about the EHR to frame the introduction about documentation, I found very few studies about nurses, and certainly no studies focused on labor and delivery. This was intriguing given the added complexity that use of the fetal monitoring system might add to nurses' experiences of the EHR. Most of the EHR literature at that time had focused on physicians and their experiences with computerized provider order entry. Studies about nurses had explored the issue by measuring the time spent documenting using time-motion studies, measuring adverse events before and after EHR implementation, or had focused on barriers and facilitators to EHR adoption. I found no research that captured the complexity I experienced and observed. From these experiences, I became keenly interested in understanding "what all is involved here?" (Schatzman, 1991), and this became the motivating factor to pursue a PhD.

Background of the Problem

The implementation of EHRs was expected to improve healthcare quality and safety, and to reduce redundancy by expanding access to information and to support tools to enhance clinical decision-making (Institute of Medicine [IOM], 2003). This includes up-to-date information such as the patient's medical history, medications, and laboratory and other diagnostic tests; making

medical knowledge needed for effective clinical decision-making readily available to clinicians; prevent medication and other types of errors through real-time alerts and decision support; and providing tools and features to enhance clinicians' cognitive work (IOM, 2003).

While studies report safety gains and improvements associated with EHRs, their use has also generated numerous unintended and adverse consequences. Gains include improved detection of potential medication errors or of critical laboratory values (Bristol, Nibbelink, Gephart, & Carrington, 2018; King, Patel, Jamoom, & Furukawa, 2014); increased adherence to clinical guidelines (Appari, Johnson, & Anthony, 2013), and increased compliance with timely medication administration (Radley et al., 2013; Swanson-Kazley & Diana, 2011). Adverse consequences include difficulty navigating and finding information in the record (Bristol et al., 2018; , Roman, Ancker, Johnson, & Senathirajah, 2017), loss of overview of the patient's status (Varpio et al., 2015), cumbersome data entry processes (Blijleven, Koelemeijer, Wetzels, & Jaspers, 2017; Kroth et al., 2018); poor interoperability between systems (Kroth et al., 2018), and incomplete information at the point of care (Sittig, Wright, Ash, & Singh, 2016).

Theoretical Framework

The prevailing paradigm informing safety interventions in the United States stems from a systems-based approach that aims to eliminate medical error and accidental harm by improving, altering or redesigning structures and processes within the healthcare system. This approach is based on the assumption that well-designed systems are capable of catching and eliminating error (Aspden, Corrigan, Wolcott, & Erickson, 2004; Emanuel et al., 2008; Page, 2004). The implementation of EHRs in U.S. hospitals was conceived as such an intervention based on the expectation that their use would improve communication and access to information, reduce

prescribing errors, assist clinical decision-making, improve adherence to clinical guidelines, and assist with data analysis for root cause analysis activities (Aspden et al., 2004; Page, 2004).

Human factors and sociotechnical systems theorists caution that systems alone are incapable of eliminating error, and that reliance on a systems-based approach to improving safety fundamentally underestimates and misinterprets the complexity and dynamic nature of healthcare work (Berg, 1999). Instead, these theorists see safety as an outcome resulting from how safety-related interventions and systems either hinder or support clinicians' performance and cognitive functioning (Karsh, Holden, Alper, & Or, 2006; Holden, 2011, Reason, 1990; 1995; 2016), and how such interventions interact with and alter the clinical work environment, culture, and social system (Harrison, Koppel, & Bar-Lev, 2007; Sittig & Singh, 2010). Furthermore, these theories emphasize that systems must not only support routine cognitive functioning and performance, but performance under problematic, challenging, or disruptive circumstances (Holden, 2011; Karsh et al., 2006), "when human performance is the last arbiter between safety and harm" (Holden, 2011 p. 2).

Cognitive Work

There is not a concise definition of cognitive work in the healthcare literature. While it might be helpful to have a tidy description, I believe there are sound reasons why it has not been defined simply, as well as important reasons to resist the temptation to oversimplify it. Cognitive systems engineers argue that all work is cognitive, and with the exception of functions regulated by the autonomic nervous system, everything we do requires some kind of thinking (Hollnagel & Woods, 2005). Certainly, attempting to define a nurse's cognitive processes outside of a holistic perspective of nurses' work is artificial and diminutive. Hence, cognitive work may be characterized as encompassing the range of mental, emotional, intuitive, and perceptual activities

that nurses engage in as they care for patients (Benner, Tanner, & Chesla, 2009). Clinical grasp (Benner, Hooper-Kyriakidis, & Stannard, 1999; Benner et al, 2009) and situation awareness (Endsley, 1995) were both helpful for developing my understanding of cognitive work. Together these frameworks describe how clinicians formulate and communicate a particular patient's clinical picture, anticipate and plan for possible clinical or illness trajectories, and apply their expertise and perceptions to the clinical situation at hand (Benner et al., 1999; 2009; Endsley, 1995). Triggered by cues in the environment or situation, these are dynamic knowledge structures that experts apply to understand evolving situations and predict future states (Wickens, 2008).

Healthcare environments have been characterized as complex sociotechnical systems (Carayon, 2006). There are numerous conceptual and analytic reasons for framing the EHR, nurses' cognitive work, and patient safety within a human factors and sociotechnical systems framework. These include: a) an understanding that the components of a sociotechnical system interact with and exert an effect on the other components, thereby continuously altering the technology, work environment, culture, and social system where clinicians perform their work (Harrison et al., 2007; Sittig & Singh, 2010); b) that safety is an emergent property in complex systems (Dekker, 2015); and, c) an understanding that the same technology is variable across settings and contexts, and can be changed and altered by local forces (including the social system, organizational factors, and the operational environment) (Harrison et al., 2007).

Dissertation Focus

When the EHR and nurses' cognitive work are viewed in the context of a complex sociotechnical system, the system-level outcome of patient safety becomes a product of the numerous relationships, interactions, and interconnections of all of the components of the

healthcare system occurring in the unique clinical setting (Dekker, 2015). The recursive and iterative nature of the interactions among the parts of a sociotechnical system may contribute to the generation of unintended consequences (Harrison et al., 2007). Hence, the research methodologies best suited to understand such outcomes in this context must be capable of revealing the complexity and various dimensions of interaction, of social processes, and of the relationship between humans and technology. The theory-methods package of symbolic interactionism and grounded theory was used for this dissertation study in order to specifically elucidate these interactions, and individual and group action (Blumer, 1969; Charmaz, 2014; Clarke, 2005).

The purpose of this grounded theory study was to explore labor and delivery nurses' perceptions of how interaction with and use of the EHR affects their cognitive work, with the goal of understanding patient safety implications.

This dissertation is organized into three papers. The first paper presents the findings from an integrative review of the literature about the impact of the EHR on nurses' cognitive work (Wisner, Lyndon, & Chesla, 2019). This manuscript has been published in the International Journal of Nursing Studies and is reprinted here with permission from Elsevier Publishing. The second paper presents findings that explore labor and delivery nurses' experiences of *configuring care* when using the EHR and how they *integrated the EHR* into their practice. The third paper presents an analysis that focuses specifically on labor and delivery nurses' use of cognitive support features in the EHR. The dissertation concludes with a final chapter summarizing and synthesizing the study results, and discusses clinical implications and directions for future research.

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Chapter 2

The Electronic Health Record's Impact on Nurses' Cognitive Work: An Integrative Review

Wisner, K., Lyndon, A., & Chesla, C. A. (2019). The electronic health record's impact on nurses' cognitive work: An integrative review. *International Journal of Nursing Studies, 94*, 74-84. doi.org/10.1016/j.ijnurstu.2019.03.003

Abstract

Background: Technology use can impact human performance and cognitive function, but few studies have sought to understand the electronic health record's impact on these dimensions of nurses' work.

Objective: The purpose of this review was to synthesize the literature on the electronic health record's impact on nurses' cognitive work.

Design: Integrative review.

Data sources: MEDLINE/PubMed, CINAHL, Embase, Web of Science, and PsycINFO.

Review Methods: The literature search focused on 3 concepts: the electronic health record, cognition, and nursing practice, and yielded 4910 articles. Following a stepwise process of duplicate removal, title and abstract review, full text review, and reference list searches, a total of 18 studies were included: 12 qualitative, 4 mixed-methods, and 2 quantitative studies from the United States (13), Scandinavia (2), Australia (1), Austria (1), and Canada (1). The Mixed Methods Appraisal Tool was used to assess the quality of eligible studies.

Results: Five themes identified how nurses and other clinicians used the electronic health record and perceived its impact: 1) forming and maintaining an overview of the patient, 2) cognitive work of navigating the electronic health record, 3) use of cognitive tools, 4) forming and maintaining a shared understanding of the patient, and 5) loss of information and professional domain knowledge. Most studies indicated that forming and maintaining an overview of the patient at both the individual and team level were difficult when using the electronic health record. Navigating the volumes of information was challenging and increased clinicians' cognitive work. Information was perceived to be scattered and fragmented, making it difficult to see the chronology of events and to situate and understand the clinical implications of various

data. The template-driven nature of documentation and limitations on narrative notes restricted clinicians' ability to express their clinical reasoning and decipher the reasoning of colleagues. Summary reports and handoff tools in the electronic health record proved insufficient as stand-alone tools to support nurses' work throughout the shift and during handoff, causing them to rely on self-made paper forms. Nurses needed tools that facilitated their ability to individualize and contextualize information in order to make it clinically meaningful.

Conclusion: The electronic health record was perceived by nurses as an impediment to contextualizing and synthesizing information, communicating with other professionals, and structuring patient care. Synthesizing and communicating information at the individual and team levels are known drivers of patient safety. The findings from this review have implications for electronic health record design.

What is already known about this topic?

- There has been widespread implementation of electronic health records in developed countries in the past decade.
- Electronic health records were expected to enhance patient safety by increasing access to information and preventing clinical errors.
- A growing body of literature suggests that electronic health records have introduced some unintended, negative consequences to cognitive processing and communication.

What this paper adds:

- The electronic health records' focus on data aggregation and completeness has introduced cognitive challenges for users as they compile and synthesize information from throughout the medical record.
- Navigating the structure of the electronic health record may not always match how nurses think and work, generating additional work to integrate it into their complex, dynamic workflow.
- Clinicians reported difficulty formulating and maintaining overview of the patient when using the electronic health record.
- Limited narrative notes in the electronic health record hindered clinicians' ability to communicate and understand others' clinical reasoning regarding care decisions.

Keywords: clinical grasp; cognitive work, communication; computerized documentation; electronic health record; integrative review; perception; situation awareness; unintended consequences

Background and Significance

The implementation of electronic health records (EHRs) was conceived as a system-level safety intervention aimed at improving communication and access to information, reducing medication-related errors, supporting decision-making, improving clinical guideline adherence, and assisting with data analysis (Aspden, Corrigan, Wolcott, & Erickson, 2004; Page, 2004). Since the widespread implementation of EHRs in the last decade, a growing body of research suggests that their use has introduced unintended consequences related to usability, alterations in communication or information exchange, and system complexity (Bristol, Nibbelink, Gephart, & Carrington, 2018; Campbell, Sittig, Ash, Guappone, & Dykstra, 2006; Cresswell, Worth, & Sheikh, 2012; Harrington, Kennerly, & Johnson, 2011; Koppel et al., 2005).

Achieving many of the quality, safety, and efficiency outcomes related to meaningful use of EHRs (HealthIT.gov, 2014) has necessitated EHR infrastructures to support the aggregation, storage, and visibility of data, as well as the creation of automated or built-in functions designed to remind and aid clinicians to compile and record information. Human factors and sociotechnical systems frameworks suggest that this focus on data completeness, aggregation and storage, and the associated work processes creates challenges for end-users. Users encounter difficulties when they try to compile and synthesize information from the EHR, and integrate cumbersome EHR-related workflows with the dynamic and demanding nature of clinical work (Holden, 2011).

Despite recognition that new technologies can impact human performance and cognitive function (Dekker, 2015; Perrow, 1999), few studies have sought to understand the EHR's impact on clinicians' cognitive work. The frameworks of clinical grasp (Benner, Hooper-Kyriakidis, & Stannard, 1999; Benner, Tanner, & Chesla, 2009) and situation awareness (Endsley, 1995)

conceptualize cognitive work as a higher order, dynamic, and evolving understanding of the patient's status, situated in a particular clinical context, and dependent on the clinician's ability to continually contextualize and synthesize data over time across information sources. Information retrieved from the EHR represents one of many important data sources used by clinicians to continually update their individual and shared perceptual understanding of clinical situations. This ability to perceive, understand, and anticipate information about a patient in evolving clinical situations is seen as a vital contributor to patient safety (McComb & Simpson, 2014). The purpose of this review was to summarize the literature about the EHR's impact on nurses' cognitive work.

Methods

An integrative review methodology was used since it allows for the synthesis of experimental, non-experimental, and theoretical data, and is particularly useful for exploring complex phenomena (Whittemore & Knafl, 2005). The steps in this method include problem identification, literature search, data evaluation, data analysis, and presentation. Problem identification is addressed in the background section.

Literature Search

The search focused on three main concepts: the EHR, cognition, and nursing practice. See **Table 2.1** for a list of all search terms used. Search terms related to cognition were challenging to define since there is no single definition of cognitive work in the healthcare literature, and there are numerous clinically relevant mental processes that may be impacted by EHR use. These include concepts and terms such as situation awareness, clinical grasp, decision-making, critical thinking, and clinical overview but also encompass mental processes such as perception, thinking, or problem solving. Some of these concepts have been identified as

secondary or incidental findings in studies focused on the EHR's impact on workflow, communication, or collaboration. Hence, search terms such as workload, workflow, work routines, and attitudes were added to capture the breadth of literature on the EHR's impact on nurses' work. This ensured that studies with incidental cognitive findings were identified. Research came from literature in three main fields: healthcare, psychology, and information science.

With assistance from a medical librarian with extensive experience searching healthcare literature, five databases were chosen based on their likelihood of containing literature related to clinical care (MEDLINE/PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Embase), psychology (Web of Science and PsycINFO), and information science (PubMed, CINAHL, Embase, Web of Science, PsycINFO). No limiters were applied in order to capture literature not yet indexed.

Data Evaluation

A total of 4910 articles were retrieved. Duplicates were removed by a reference manager software and by hand. The titles and/or abstracts of the remaining 3821 records were screened according to inclusion and exclusion criteria, and 3801 were excluded, leaving 20 articles to assess for eligibility. During full text review, 6 articles were excluded based on inclusion criteria. The reference lists of eligible records were reviewed and work by prominent EHR researchers was searched to ensure data completeness (Whittemore & Knafl, 2005), adding 4 additional records. A total of 18 records met eligibility criteria for this review. See **Figure 2.1** for the stepwise process used for study selection.

Inclusion criteria. Studies had to meet the following inclusion criteria: a) written in English; b) be original qualitative, quantitative, or mixed methods research published in a peer-

reviewed journal; c) sample included direct-care nurses in hospital settings; and either d) the study reported findings related to the EHR's (or synonym) effect on nurses' cognitive work as defined in the mental processes/cognition search terms; or, e) the study outcomes included concepts related to collaborative decision-making or team situation awareness.

Exclusion criteria. Studies were excluded if they met any of the following criteria: a) focused on technology or computers generally instead of the EHR (or synonym); b) EHR use was secondary to EHR-related features or processes such as displays, software, checklists, care plans, or decision support; d) focused on EHR implementation strategies, or user adoption, satisfaction, acceptance or perceptions, where cognition was not part of the findings; e) focused on workflow, productivity, or documentation time with findings unrelated to cognition; or f) the study focused on computerized physician order entry without evaluating other elements of the EHR.

Quality appraisal. The Mixed Methods Appraisal Tool ([MMAT], Pluye et al., 2011) was used to appraise the quality of eligible studies. The MMAT is designed to evaluate the methodology of quantitative, qualitative, and mixed-methods research studies. Each study was assessed according to MMAT criteria based on the study methodology, which included qualitative, quantitative (further delineated by type: randomized controlled trial, non-randomized, and descriptive), and mixed methods. The appraisal process involved scoring 4 quality questions for each study type, and another 3 questions for mixed-methods studies. Examples of criteria addressed in the scored questions for qualitative studies included data quality and sources, analytic processes, and researcher positionality. The quantitative questions varied according to study type, but in general addressed sampling strategy and/or representativeness, measurement processes, and response rates. Mixed methods questions

addressed research design and appropriate integration of methods (Pluye et al., 2011). One point was assigned for each of the 4 questions meeting defined criteria, yielding an overall score of 0-4. When scoring mixed-methods studies, the lowest of the quantitative and qualitative scores was assigned according to the scoring guidelines, since the overall quality of a study is reflected by its weakest element (Pluye et al. 2011).

All studies were first screened using two questions about the clarity of the research questions or objectives and if appropriate data were collected to address these. Pluye and colleagues (2011) caution that if the answer to either screening question is no or unknown, further appraisal may not be appropriate. Because the body of literature for this integrative review was limited, certain studies were included when the response to one of the screening questions was unknown. If the answer to both screening questions was no or unknown, the study was excluded. See **Table 2.3** for a summary of MMAT scores assigned to each study.

Results

Data Analysis

Eighteen studies met eligibility criteria. See **Table 2.3** for a summary of included studies. Twelve studies were qualitative (grounded theory, interpretive phenomenology, ethnography, content analysis, thematic analysis, network analysis, interpretive descriptive). Four were mixed-methods, and two were quantitative descriptive. Publication dates ranged from 2004 to 2016. Studies were from the United States (13), Scandinavia (2), Australia (1), Austria (1), and Canada (1).

Instruments used in the quantitative and mixed-methods studies included the NASA-TLX: Task Load Index (1), an amended Health Information Systems (HIS)-monitor instrument (1), the Information Systems Expectations and Experiences (ISEE) survey (1), an adapted

Masrom's Technology Acceptance Model and E-learning survey (1), and researcher-developed surveys (2). Interviews (8), focus groups (5), observations (8), think-aloud and think-after sessions (1) and artifacts analysis (7) were used alone or in combination in the mixed-methods and qualitative studies. One study used network analysis.

The quality of the studies evaluated using the MMAT ranged from 1-3 (0-4 scale), with 9 studies considered moderate quality (MMAT score ≥ 3), and 9 as low quality. One point was deducted for half of the qualitative studies because researcher positionality was not addressed (Pluye et al., 2011). These six studies would have been judged high quality (4 on a scale of 0-4) had that been included (Collins, Bakken, Vawdrey, Coiera, & Currie, 2011; Embi et al., 2013; Keenan, Yakel, Dunn Lopez, Tschannen, & Ford, 2013; Staggers, Clark, Blaz, & Kapsandoy, 2011, 2012; & Varpio et al., 2015). See **Table 2.3** for an overview of methods, instruments, and MMAT scores for all studies.

Twelve of the studies focused on RNs only. The other six studies focused on physicians and RNs (3); midwives and RNs (1), and multiple stakeholders including RNs (2). Most studies were conducted in inpatient acute care units within community or tertiary hospitals. Inpatient units included pediatrics, neonatal intensive care, perinatal, medical surgical, oncology, orthopedic, and critical care settings. One study was conducted in 25 different practice settings across Australia. Another study took place in 4 U.S. Veterans Administration sites. The focus of the studies included clinician perceptions of the EHR; its impact on collaboration, communication, practice and workflows, care coordination or information processing; overall effect on work, use of the EHR during handoff, evaluation of cognitive artifacts in the EHR, and measurement of cognitive workload.

Five themes were identified: 1) forming and maintaining overview of the patient, 2) the cognitive work of navigating the EHR, 3) the use of cognitive tools, 4) forming and maintaining common ground and a shared understanding of the patient, and 5) the loss of information and professional domain knowledge. See **Table 2.2** for an overview of themes. In the following sections, we use the term *nurses* for results from studies with nurses only and when distinct findings for nurses were reported. In studies with nurses and other clinicians, and when findings were not delineated by provider group, we use the term *clinicians.*

Data Presentation

Forming and Maintaining Overview of the Patient. Eleven of the studies reported on clinicians' ability to obtain or maintain an overview of the patient. Most findings indicated that forming and maintaining an overview of the patient's status is complex and difficult when using the EHR. While the EHR has facilitated the ability to collect and store vast amounts of information, findings suggested that this information often lacked clinical utility.

Overview was described as a vital and dynamic clinical skill that resulted in a cumulative and comprehensive understanding of the patient's history, current status, data patterns and future plan of care (Varpio et al., 2015). Clinicians assembled overview by consolidating, analyzing, interpreting and contextualizing various data derived from their own and others' assessments and communications, the medical record, patient history, and interactions with patients and colleagues. Overview represented a synthesis of information and a cognitive framework that clinicians used to guide their thinking, interpret and respond to clinical findings and data, and to anticipate the patient's clinical trajectory (Varpio et al., 2015). While the process of assembling and synthesizing information across data sources, and contextualizing and synthesizing information was described differently in various studies, it was seen as fundamental to the

process of forming the big picture or overview of the patient and supporting clinical work (Embi et al., 2013; Keenan et al., 2013; Staggers, Clark, Blaz, & Kapsandoy, 2011; Staggers, Clark, Blaz, & Kapsandoy, 2012; Stevenson & Nilsson, 2011; Varpio et al., 2015; Weir et al., 2011).

While template-driven documentation facilitated data entry, the information generated was less informative than free text documentation (Embi et al., 2013). The emphasis on documentation completeness and increased volume of information in the record made it difficult to readily locate and process desired content, thus diminishing its clinical usefulness and failing to offer a concise summary of the patient's status (Embi et al., 2013). The EHR facilitated the collection and storage of more information; however, it scattered and fragmented parts of the patient's story, distributing pieces throughout the record (Chao, 2016; Schenk et al., 2016; Varpio et al., 2015; Vikkelsø, 2005). This made the process of consolidation, interpretation, and synthesis more difficult to achieve, complicating clinicians' ability to acquire a summative understanding of the patient's status (Varpio et al., 2015), and did little to facilitate the understanding and synthesis needed by clinicians to support their cognitive work (Weir et al., 2011). Vikkelsø (2005) reported that overview was particularly difficult to obtain surrounding the patient's medications, and that the work of assembling overview for the care team was taken up informally by nurses.

Findings from studies examining nurses' handoff processes and information management and flow reported lack of a standardized overview in the EHR, causing nurses to rely on paper forms containing their personal notes (Keenan et al., 2013; Staggers et al., 2011, 2012). Chao (2016) also reported this in a study examining collaborative work routines. These paper forms contained synthesized, dynamic information derived from various sources, tailored by nurses to both align with and support their work throughout the shift and during handoff (Chao, 2016;

Staggers et al., 2012, 2011). These synthesized data provided the cognitive support needed for nurses to prioritize and organize their work and were not available in the EHR despite it containing an electronic summary intended for this purpose (Chao, 2016; Staggers et al., 2012, 2011). In particular, the electronic summary lacked contextual information necessary to formulate an overview such as vital sign trends, or the integration of information such as seeing medications in the context of vital signs or with pertinent laboratory data (Staggers et al., 2011).

Clinicians found the narrative note features and processes in the EHR problematic. Across several studies, the visibility of colleagues' thought processes (including their intentions, clinical interpretations, and reasoning) was fundamental to achieving an overview the of patient's clinical status (Embi et al., 2013; Varpio et al., Weir et al., 2011). The EHR restricted the amount and quality of narrative notes which hindered clinicians' ability to both share and decipher the intentions and clinical reasoning behind care decisions and activities (Embi et al., 2013; Varpio et al., 2015; Weir et al., 2011). Like other information in the EHR, narrative notes were fragmented and scattered across the medical record, making it difficult to formulate a chronological narrative (Varpio et al., 2015). Clinicians described the process of sorting and interpreting information in narrative notes to reconstruct the chronology of events as cumbersome and difficult (Weir et al., 2011). They had difficulty reconstructing details about the patient's course of care across various problems and encounters, which hindered their ability to decipher symptom patterns and the course of disease (Embi et al., 2013), and created undue cognitive work as they compiled data from across the record to build the patient's story (Varpio et al., 2015).

One mixed-methods study reported improved overview when using the EHR; however, this was based on favorable responses to several survey questions that evaluated perceptions

about access to information and visibility of open tasks, supported by content analysis of open-ended responses (Ammenwerth, Rauchegger, Ehlers, Hirsch, & Schaubmayr, 2011). Other studies using immersive data collection methods such as interviews, observations and artifact analysis suggested that access to and visibility of information in the medical record did not enhance overview, and in many cases rendered information opaque and more difficult to interpret. Stevenson and Nilsson (2011) and Schenk and colleagues (2016) reported mixed findings about overview. In both studies, nurses felt that access by multiple users to the medical record was advantageous, and that information in the EHR was more comprehensive; however, this information was fragmented (Schenk et al, 2016), difficult to retrieve and synthesize, and challenged users' ability to track the patient's progress (Stevenson & Nilsson, 2011), making the increased volume of information less useful.

The Cognitive Work of Navigating the EHR. Fourteen studies reported findings related to navigation in the EHR and its effect on cognitive workload or cognitive support. Most findings indicated that entering, retrieving, understanding, and synthesizing information was difficult in the EHR and increased clinicians' cognitive work or failed to provide necessary cognitive support. These issues were related to the scattering or fragmenting of information, information overload or complexity, poor quality of information, inability to decipher intent and clinical reasoning, and lack of chronology.

Findings related to access to and usefulness of information needed for certain aspects of cognitive work were mixed. Kossman and Scheidenhelm (2008) reported improved access to information needed for decision-making, and better organization of information and tasks within the EHR, thus enhancing nursing work. A study using the Health Information Systems (HIS)-monitor instrument reported improved information processing, including support for compiling

the patient's medical history and other information for the admission process and for creating and updating the care plan (Ammenwerth et al., 2011). On the other hand, a study using the Information Systems Expectations and Experiences Survey (ISEE) reported that nurses felt less confident that they had access to the right information for patient care and reported poorer access to information that improved their ability to make good patient care decisions (Ward, Vartak, Schwichtenberg, & Wakefield, 2011).

Other investigators suggested that clinically relevant information retrieval from the EHR was difficult and cumbersome (Collins, Bakken, Vawdrey, Coiera, & Currie, 2011; Darbyshire, 2004; Weir et al., 2011, Zadvinskis, Chipps, & Yen, 2014). Processes such as inputting and locating vital signs during care were perceived as problematic (Stevenson & Nilsson, 2012). Clinicians found it hard to search across documents located throughout the medical record to find relevant information. The EHR scattered and fragmented information, making its retrieval and synthesis challenging. This created more cognitive work for clinicians and did not provide the cognitive support needed to synthesize and understand the information (Chao, 2016; Embi et al., 2013; Schenk et al., 2016; Varpio et al., 2015; Zadvinskis et al., 2014).

Finding relevant, clinically meaningful information from lengthy printouts or screens containing irrelevant, truncated, or outdated information increased clinicians' cognitive work (Chao, 2016; Embi et al., 2013; Staggers et al., 2012; Varpio et al., 2015; Weir et al., 2011), and impeded the interpretive process central to synthesizing and comprehending information (Varpio et al., 2015). When clinicians detected that the copy and paste function was used for narrative notes, they mistrusted the currency and accuracy of information, and engaged in more cognitive work to validate and cross-check such data (Weir et al., 2011).

One study used the NASA-TLX to assess cognitive workload during data entry and retrieval tasks in a matched sample of 74 nurses. The survey was administered prior to EHR implementation, at the end of each nurse's 1st, 5th, and 10th work shifts post-implementation, and again at 4 months post-implementation (Colligan, Potts, Finn, & Sinkin, 2015). Cognitive workload was statistically significantly higher for nurses after their 1st and 5th work shifts, returning to baseline for most participants by their 10th shift, suggesting that cognitive challenges were limited to the early implementation period.

The Use of Cognitive Tools. Ten of the studies focused on or reported incidental findings about the cognitive tools available in the EHR. In all these studies, available EHR-generated summary reports and screens were seen as insufficient as stand-alone tools to support nurses' information management throughout the shift or surrounding handoff. Nurses reported that these EHR summary report tools and templates did not match how they thought and worked, resulting in the persistence of paper forms or reliance on verbal exchanges.

Across several studies, nurses did not use available EHR-generated summary reports during the shift or for handoff. When used, nurses augmented and tailored them to provide missing information (Chao, 2016; Staggers et al., 2011; 2012). Some nurses found printouts such as medication administration records, flowsheets, orders and care plans helpful, but still relied heavily on personal notes and scraps of paper that they continually updated and revised throughout the shift to support handoff (Keenan et al., 2013). Most EHR-generated summary tools were too long and contained truncated or extraneous information and did not meet nurses' needs for a concise (Chao, 2016), contextualized, synthesized summary (Staggers et al., 2011; 2012). Nurses tailored their paper forms to contain the significant information they needed to know, using these forms to plan and organize activities individually and collectively for assigned

patients, as well as to collect and synthesize information throughout the shift (Keenan et al., 2013; Staggers et al., 2011; 2012). This recorded content helped nurses to structure clinical judgments and prioritize and plan actions for the day. Writing on the forms was not just about collecting information; nurses reported that it supported how they remembered and processed their thoughts, and helped them verify that they had pertinent information to structure their work for the shift (Staggers et al., 2011; 2012). Nurses wanted to tailor self-made or EHR-generated tools to each patient; for example, they may forgo certain demographic data on patients who were familiar to them, or add highlighted information that required special attention or vigilance such as a high-risk medication that required specific timing (Staggers et al., 2011).

Nurses used their paper forms more often after EHR implementation for handoff and throughout the shift to mitigate new documentation issues encountered with the EHR. They found they were using these self-made forms to track information and document later, resulting in duplicate documentation (Chao, 2016). The EHR's focus on the aggregation and storage of information was at odds with clinical work (Chao, 2016) and yielded electronic tools that were too generic and cluttered with immaterial information to be useful to nurses as they planned and performed their work (Staggers et al., 2011; 2012).

Clinicians found information retrieval from their personal notes or verbal communication easier than from the EHR, causing an increased reliance on verbal exchanges (Collins et al., 2011). They wanted succinct and up-to-date summaries of the patient's status and overall goals of care, and found the templated and exhaustive information in the EHR confusing, limiting their ability to understand the course of care (Embi et al., 2013). Nurses reported that documentation in the EHR did not match the fast-paced, mobile and team-based nature of their work. Tools and structures in the EHR were difficult to access and use, forcing duplicative documentation, first

on paper notes and later in the EHR (Embi et al., 2013). Nurses reported frustration that support for patient care was not built into the EHR (Schenk et al., 2016). The physical assessment templates did not correspond to how nurses performed and thought about their assessment, resulting in inefficiency and frustration (Zadvinskis et al., 2014), and the mandate to document a care summary in shift notes was at odds with their continuous data collection and entry (Embi et al., 2013).

Kossman, Bonney, and Kim (2013) evaluated seven cognitive artifacts for their support of nurses' clinical judgment and communication. These included six EHR-generated tools and the nurses' self-made worklists. Nurses rated their self-made worklists as more useful overall for clinical judgment and communication than any of the EHR-generated tools except for the medication administration record. The EHR-generated templates, problem lists and summary reports failed to organize and display information in ways that aligned with and supported important aspects of nursing work (Kossman et al., 2013; Staggers et al., 2011), such as how they were accustomed to finding information and thinking about their patients (Staggers et al., 2011). The self-made tools organized and displayed information in a way that supported their workflow and style by making information portable, easily accessible and prompting memory (Kossman et al., 2013, Staggers et al., 2011). While work lists and automated alerts in the EHR enhanced efficiency and aided memory, and information for clinical decision-making was more accessible, nurses expressed concern that heavy reliance on drop-down menus, cut and paste features, and checkboxes could impair their critical thinking and documentation accuracy (Kossman & Scheidenhelm, 2008).

Simply having information in a printout or screen was insufficient, since individualizing and contextualizing information was integral to synthesizing the information in a clinical

context. For example, nurses wanted to see vital sign trends, view the patient's apical pulse when giving a cardiac medication, or evaluate clotting factors when giving a blood thinner (Staggers et al., 2011). Findings suggested that nurses engaged more readily in this process of contextualizing and individualizing information when using their self-made tools, as opposed to the EHR-generated tools that did not provide sufficient support (Staggers et al., 2011; 2012).

Forming and Maintaining Common Ground and a Shared Understanding of the Patient. Eight studies reported findings related to some aspect of clinician/team communication or the EHR's effect on care coordination, collaborative decision-making, and achieving common ground and a shared understanding of the patient's status. Common ground refers to individuals having a mutual understanding of a situation, and shared situation awareness (or understanding) refers to having a mutual understanding of its meaning (Weir et al., 2011). The findings indicated that communication—the fundamental element required for clinicians to organize and advance a shared understanding of the patient's status—was not enhanced by the increased volume and exchange of information and data. Instead, clinicians needed access to contextualized information that helped them form and maintain common ground and to expedite a shared situation awareness (Weir et al., 2011), especially in uncertain and dynamic clinical situations.

The EHR provided limited support for interprofessional communication and care coordination (Chao, 2016; Keenan et al., 2013), and nurses' use of verbal communication with physicians increased after EHR implementation, presumably because computer-mediated communication was insufficient for understanding physicians' intentions (Chao, 2016). The EHR contained a structure for orders and shared goals (such as documenting the plan of care in a physician's note), and alerting functions regarding abnormal findings, such as laboratory values. However, the EHR provided insufficient support for activities like collaborative decision-

making, conveying updates aimed at establishing a shared understanding of the clinical situation, or contextualizing certain clinical findings relative to a patient's case (Collins et al., 2011). The EHR did not facilitate deciphering and prioritizing goals and understanding the clinical reasoning behind orders, and did not facilitate communication of information needed to establish common ground during uncertain or evolving clinical situations, as with unstable patients (Collins et al., 2011).

Clinicians felt the EHR was inadequate as a single information source, and multiple modes of communication were required to support effective clinical communication and care coordination (Embi et al., 2013). This was especially problematic since clinicians reported that the EHR changed work routines in a way that reduced their direct communication with each other (Embi et al., 2013). Nurses reported continued reliance on verbal report to ensure an understanding of the patient and care priorities (Stevenson & Nilsson, 2011).

As noted in other themes in this review, narrative notes were appreciably limited in EHR documentation, which emphasized capturing objective information via drop-down features, check boxes, and other preconfigured templates. Features and structures in the EHR impeded clinicians' ability to decipher colleagues' interpretations and subjective impressions of the patient's status (Varpio et al., 2015; Weir et al., 2011), resulting in loss of shared situation awareness. Clinicians identified the process of reading colleagues' notes and their interpretations, intentions, and clinical reasoning as central to how they formed and maintained an individual and shared understanding of the patient's status and clinical trajectory. Loss of access to others' reasoning impeded the team's collective work of developing this shared understanding (Varpio et al., 2015). Deciphering the meaning of the situation relied on being able to see the chronology of events and linkages between certain data and points in time, as well

as being able to extract and synthesize relevant and temporal information from the vast stores of information in the medical record (Weir et al., 2011). The copy and paste functions in the EHR were frequently used and produced narrative notes that were cluttered and missing a sense of dialogue and interpretation (Weir et al., 2011).

Some findings were mixed. While there was better coordination of certain aspects of the patient's case—in particular the medical aspects of care (medications, diagnosis), the EHR led to a diminished focus on nurses' perspectives and care activities. Ways to represent psychosocial aspects of care and the patient's perspective were reduced and thus there were fewer opportunities for this information to be shared among the team (Vikkelsø, 2005).

The Loss of Information and Professional Domain Knowledge. Nine studies reported findings related to lost or missing information. A subtheme was the continued reliance on personal notes, scraps of paper, or other disposable forms of documentation, which may have implications related to information loss if such information is not recorded in the EHR. In numerous studies, representations of nurses' work and knowledge were not captured in the EHR, or nurses' notes were not read, which suggests that in certain settings the work and knowledge of nursing is not integrated into team processes.

Several studies reported increased variability and inconsistency in where data were documented (Chao, 2016; Kossman & Scheidenhelm, 2008; Stevenson & Nilsson, 2011), leading to frustration and possibly overlooked information (Kossman & Scheidenhelm, 2008). Input fields that were grouped in related sections in the paper chart were missing in certain EHR-generated forms or were difficult to find. This caused nurses to document in text boxes, often in different places throughout the record (Chao, 2016). Nurses avoided the use of templates because they were difficult to use, leading to inconsistency in where certain data were charted.

Nurses were concerned about missing or overlooking important information because it was complex to input and locate (Stevenson & Nilsson, 2011). Preconfigured checklists or templates did not always contain details that matched the clinical situation; for example, a screen may have a drop down for staples, when the patient instead had sutures (Kossman & Scheidenhelm, 2008). In such cases, nurses had to decide whether to chart inaccurately, take time to navigate to another part of the record to enter a note, or not to document the finding (Kossman & Scheidenhelm, 2008).

Clinicians found it difficult to navigate the EHR and to locate relevant information in cluttered screens (Embi et al., 2013). They coped with this by selectively reading narrative notes which left them concerned that they had missed or overlooked important information (Embi et al., 2013). Nurses' notes were not read by other disciplines (Kossman & Scheidenhelm, 2008), because their formats required too much work to navigate and understand (Weir et al., 2011). This led to increased verbal exchanges or loss of information (Kossman & Scheidenhelm, 2008; Weir et al., 2011). Nurses reported a delay in being able to access and read physician notes from the emergency department and notes from morning rounds reflecting team decisions made during that time (Embi et al., 2013).

Certain care activities were not found in the EHR, such as patient safety double-checks and the evaluation of goals (Collins et al., 2011). Alerts and notifications about laboratory findings changed from a linear process managed by ward clerks to a continuous notification process embedded in the EHR. While critical laboratory results were more readily flagged, other results were overlooked or lost in the record (Vikkelsø, 2005). When a patient had numerous abnormal findings, nurses found it difficult to navigate the medical record to find where to

document various findings, potentially leading to lost or overlooked information (Schenk et al., 2016).

There was no centralized overview function accessible by all clinical team members. Given the rarity of interdisciplinary communication and very limited time spent on the units by non-nursing members of the team, it was unlikely that nursing knowledge was accessed and used by other disciplines (Keenan et al., 2013). While nurses' autonomous actions and decision-making were apparent during observations, these were not represented in the EHR (Collins et al., 2011). Another study reported a shift in focus to the medical versus nursing or patient-centered aspects of care when using the EHR, leading to loss of nurses' and patients' perspectives (Vikkelsø, 2005).

Discussion

This review summarized the literature on the EHR's impact on nurses' cognitive work. Five themes were identified that described how nurses and other clinicians perceived and used the EHR. These were 1) forming and maintaining an overview of the patient, 2) the cognitive work of navigating the EHR, 3) the use of cognitive tools, 4) forming and maintaining common ground and a shared understanding of the patient, and 5) loss of information and professional domain knowledge.

Most findings indicated that forming and maintaining an overview of the patient at both the individual and team level was difficult when using the EHR. The work of navigating the vast volumes of information in the EHR to locate, contextualize, and synthesize relevant clinical information was challenging and increased clinicians' cognitive work. The EHR scattered and fragmented information, making it difficult for clinicians to see the chronology of events and to situate and understand the clinical implications of various data. The template-driven nature of

documentation and limited narrative note functions in the EHR created difficulties and increased cognitive work for clinicians as they attempted to express their clinical thinking and reasoning, and decipher that of colleagues. The EHR-generated cognitive tools such as summary reports and handoff tools were insufficient as stand-alone tools to support nurses' work throughout the shift and during handoff, resulting in reliance on self-made paper forms or augmented or tailored EHR-generated tools. Nurses needed tools that helped them individualize and contextualize information to make it clinically meaningful. These were dynamic tools used throughout the shift, representing synthesized information across data sources. Information overload caused clinicians to selectively read narrative notes, usually bypassing those written by nurses, suggesting that certain professional domain knowledge and perspective may be lost or buried in the medical record. In addition, nurses' reliance on paper forms or scraps of paper may lead to clinically important information not being transferred into the record.

These findings suggest that the increased collection, aggregation and storage of information in the EHR has not led to increased access to clinically meaningful information. The challenges that nurses and other clinicians encounter when attempting to contextualize and synthesize information have important implications for the ability to achieve and maintain clinical grasp and situation awareness, which are clearly defined cognitive processes that affect how clinicians maintain safety (Benner et al., 1999; 2009; Endsley, 1995). Information retrieved from the EHR represents one of many important data sources used by clinicians to continually update their individual and shared perceptual and mental models of the clinical situation. Mental models represent rich, dynamic knowledge structures that clinicians use to understand and anticipate evolving clinical situations and are a vital driver of patient safety (McComb & Simpson, 2014). A novel finding in this review is that clinicians relied on seeing and

understanding others' clinical reasoning, interpretations, and intentions as part of their understanding of a patient's clinical status—a process they found more challenging when using the EHR. The EHR's focus on template-driven documentation, data completeness, and serving as an information repository does not provide the types of information exchanges that support effective communication. Coiera (2000) posited that information access and communication are different processes, and certain communication cannot be executed using information technology. Clinicians look to each other when working through their interpretations and deciding on a course of action and this interaction is part of an ongoing and iterative process of updating a dynamic understanding of the situation at hand (Coiera, 2000).

Studies of physicians' perceptions of the EHR and computerized physician order entry have reported findings that align with the main themes in this review including loss of overview, fragmentation of data, increased cognitive work when navigating the EHR, and difficulty deciphering colleagues' clinical reasoning or intent (Ash, Berg, & Coiera, 2004; Ash, Sittig, Dykstra, Campbell, & Guappone, 2009; Holden, 2011). Workflows in the clinical environment and EHR use in real life are rarely linear and predictable (Hazelhurst, McMullen, Gorman, & Sittig, 2003); therefore, effectively evaluating EHR impact requires consideration of the interactions between clinician, technology, the environment, and the social system (Harrison et al., 2007; Karsh, Holder, Alper, & Or, 2006).

Some findings in this review suggest that the EHR enhances or improves some aspects of cognitive work. In most cases, the conclusion is based on the assumption that increased visibility of or access to information, having information available to multiple users, data completeness, readability or legibility, or automated data entry enhanced cognition (Ammenwerth et al., 2011; Chao, 2016; Embi et al., 2013; Kossman & Scheidenhelm, 2008; Staggers et al., 2012; Stevenson

& Nilsson, 2012; Ward et al., 2011). In most cases these were a small part of overall findings suggesting that use of the EHR creates cognitive challenges (Chao, 2016; Embi et al., 2013; Kossman & Scheidenhelm, 2008; Staggers et al., 2012; Stevenson & Nilsson, 2012). Studies that use immersive data collection methods such as interviews, observations and artifact analysis suggest that access to and visibility of information in the medical record does not enhance overview or ready access to the information needed to support clinicians' cognitive work (Chao, 2016; Collins et al., 2011; Embi et al., 2013; Keenan et al., 2013; Staggers et al., 2011; 2012; Varpio et al., 2015; Vikkelso, 2005; Weir et al., 2011).

One study sought to evaluate mental workload directly using the NASA-TLX: Task Load Index (Colligan et al., 2015), a tool that measures the operator's subjective assessments of workload using six questions focused on the mental, physical and temporal demand of a task, how much effort was required, its perceived effect on performance, and the level of frustration experienced (Hart & Staveland, 1988). This tool was used to measure narrowly defined aspects of cognitive work during and shortly after the EHR implementation period. When viewing cognitive work through the lenses of clinical grasp and situation awareness (Benner et al., 1999; 2009; Endsley, 1995), a tool such as the NASA-TLX as a stand-alone measure is likely incapable of capturing the complexity of cognitive work.

Limitations. Most of the studies in this review sought to evaluate nurses' or clinicians' overall perspectives about the EHR or its effect on work, communication, or collaboration. Aside from the study using the NASA-TLX to measure cognitive/mental workload (Colligan et al., 2015), and a mixed-methods study that measured the quality of information processing using an unvalidated HIS-monitor instrument (Ammenwerth et al., 2011), few studies set out to explore the impact of the EHR on a clearly defined aspect of clinicians' cognitive work (Kossman et al.,

2013; Staggers et al., 2011, 2012; Varpio et al., 2015). Several studies using immersive qualitative methods reported incidental findings related to cognition supported by rich and substantive data elements (Chao, 2016; Embi et al., 2013; Keenan et al., 2013; Weir et al., 2011). In the remaining studies, cognitive work was reported as an incidental finding, and in some cases the report lacked substantive data elements to support such conclusions (Collins et al., 2011; Darbyshire, 2004; Kossman & Scheidenhelm, 2008; Schenk et al., 2016; Stevenson & Nilsson, 2012; Vikkelso, 2005; Zadvinskis et al., 2014). While rigor was enhanced by a comprehensive search of the literature in five databases, all phases of data evaluation, extraction and analysis were conducted by one researcher, which may have led to bias.

Strengths. This comprehensive review of the literature is the first to attempt to summarize and evaluate how EHR use affects nurses' cognitive work. Concepts from clinical grasp (Benner et al., 1999; 2009) and situation awareness (Endsley, 1995) were used to conceptualize cognitive work as a higher order, dynamic, and evolving understanding of the patient's status, situated in a particular clinical context, and dependent on the clinician's ability to continually contextualize and synthesize data across information sources. This review identified only a few studies that have focused on clearly defined aspects of cognitive work using immersive qualitative methods, representing a gap in the literature.

Implications for Future Research

Using a human factors and sociotechnical systems framework, future research should focus on understanding how nurses retrieve, organize, synthesize, and communicate information; how they achieve and maintain clinical grasp and situation awareness when using the EHR; and exploring information technology design that supports cognitive work. Practical research applications might include how to effectively integrate narrative notes in the EHR as an

organizing aspect of clinical practice; evaluate handoff and tracking tools and align them with how nurses think and work; and focus on best practices for clinician input on information technology design to ensure content in preconfigured templates is clinically meaningful and organized in ways that support clinical work.

Conclusion

Findings from this review challenge the assumption that EHRs have improved communication, access to information, and assisted with clinical decision-making (Aspden et al., 2004; Page, 2004). Instead, findings suggest that EHR use has generated numerous cognitive challenges for clinicians that may have important safety implications. The EHR's focus on data completeness, aggregation, and storage has produced vast volumes of information that clinicians find difficult to navigate and synthesize, making clinically meaningful information less accessible and available. Nurses found that the structure of the EHR did not always match how they thought and worked, which generated additional work to integrate EHR use into their complex and dynamic workflows. The EHR's focus on data completeness needs to be balanced with design features and structures that make relevant clinical information readily accessible for clinicians without creating undue cognitive burden.

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Table 2.1 *Search Terms Used*

Search Terms Used for Each Concept		
Electronic Health Record	Nursing	Mental Processes/Cognition
Electronic health record/s Electronic medical record/s Electronic documentation Computerized documentation Electronic charting Computerized medical records systems Computerized patient documentation EMR EHR	Primary nursing Nursing Nursing care Nurse's role Nursing staff Nursing process Nurse(s) Nurs*	Mental Processes Cognition Workload Mental workload Workflow Work routines Clinical reasoning Clinical decision making Decision making Situation awareness Clinical overview Patient story/ies Clinical summary/ies Distraction/s Perception/s Perspective/s Thinking Cognitive function Human performance Information seeking behavior Critical thinking Mental performance Narratives Problem solving Psychology Unintended consequence/s Attitude to computers

Table 2.2 *Summary of Themes*

Forming and Maintaining Overview of the Patient	Studies suggested that clinicians found the process of forming and maintaining overview of the patient challenging when using the EHR. Overview has been defined as a dynamic clinical skill that resulted in a cumulative and comprehensive understanding of the patient's history, current status, data patterns and future plan (Varpio, et al., 2015).
The Cognitive Work of Navigating the EHR	In most studies, clinicians found that entering, retrieving, understanding, and synthesizing information was difficult in the EHR and either increased clinicians' cognitive workload or failed to provide necessary cognitive support.
The Use of Cognitive Tools	The available EHR-generated summary reports and screens were insufficient as stand-alone tools to support nurses' information management during their shift and/or at handoff. These tools often did not match how nurses thought or worked, resulting in reliance on paper notes and verbal exchanges.
Forming and Maintaining Common Ground and a Shared Understanding of the Patient	Findings indicated that the increased volume and electronic exchange of information did not enhance communication in a way that facilitated arriving at common ground and shared situation awareness. Common ground refers to having a mutual understanding of a situation, and shared situation awareness (or understanding) refers to having a mutual understanding of its meaning.
The Loss of Information and Professional Domain Knowledge	Nurses relied heavily on paper notes and other disposable forms of documentation, which may have implications for loss of information when this is not recorded in the EHR. Representations of nurses' work and knowledge were not captured in the EHR, or nurses' notes and documentation were not read by others, suggesting that in certain settings, nurses' work and professional knowledge is not integrated into team processes.

Table 2.3 *Overview of Studies*

	Citation	MMAT Score	Methods	Study Focus	Contribution to Themes*
Mixed Methods	Ammenwerth et al. (2011)	MM-1	Health Information Systems (HIS)-monitor instrument; content analysis of open-ended questions	Information processing	A, B
	Chao. (2016)	MM-3	Case study, thematic analysis, network analysis, researcher-developed survey, interviews, observations, artifact analysis	Collaborative work routines, interdisciplinary communication	A, B, C, D, E
	Kossman et al. (2013)	MM-2	Mixed methods convergent, descriptive. Researcher-developed survey, content analysis of open-ended questions, focus groups	Cognitive artifacts support of clinical judgment and team communication	C
	Schenk et al. (2016)	MM-1	Mixed methods; pre- post-survey and interviews. Adapted survey. Qualitative method not stated but consistent with content or thematic analysis.	RN perceptions, ease of use, usefulness, attitudes	A, B, C, E
Quant	Colligan et al. (2015)	Quan-3	Quantitative descriptive, NASA-TLX	Cognitive workload, computer attitudes, EHR implementation	B
	Ward et al. (2011)	Quan-2	Quantitative; descriptive. Information Systems Expectations and Experiences (ISEE) Survey.	Implementation, RN perceptions	B
Qual	Collins et al. (2011)	Qual-3	Clinical communication space and distributed cognition frameworks used to analyze and map data. Ethnographic observations, interviews, focus groups	Types of communication and information activities during interdisciplinary rounds	B, C, D, E
	Darbyshire. (2004)	Qual-2	Qualitative, Interpretive Phenomenology. Focus groups	Perspectives and understandings of EHR	B
	Embi et al. (2013)	Qual-3	Qualitative, cross-sectional. Thematic analysis. Focus groups	Computerized documentation effect on clinician's work	A, B, C, D, E
	Keenan et al. (2013)	Qual-3	Qualitative, content analysis. Ethnographic observations, artifact analysis.	Information management and flow, communication patterns, use of artifacts	A, C, D, E
	Kossman & Scheidenhelm. (2008)	Qual-2	Researcher-developed survey w/open ended questions to explore boundaries of phenomena, interviews, observations. Analysis not clear, consistent with thematic analysis.	EHR use during care, RN practice patterns, problems with EHR use, patient outcomes	B, C, E
	Staggers et al. (2012)	Qual-3	Qualitative; interpretive, descriptive. Audiotaped handoffs, interviews, observations, field notes, artifact review	Handoff, use of cognitive artifacts	A, B, C
	Staggers et al. (2011)	Qual-3	Qualitative; interpretive, descriptive. Audiotaped handoffs, interviews, observations, field notes, artifact review	Handoff, electronic summary reports	A, C
	Stevenson & Nilsson. (2012)	Qual-2	Qualitative; content analysis. Focus groups.	Use of EHR, overview, medication module	A, B, D, E
	Varpio et al. (2015)	Qual-3	Qualitative; constructivist grounded theory. Observations, interviews, artifact analysis, think-aloud and think-after sessions.	Building the patient's story when using the EHR	A, B, D
	Vikkelsø. (2005)	Qual-2	Qualitative, grounded theory, actor-network theory. Observation, field notes, artifacts analysis, photos, interviews	Practice, workflows, interaction	A, D, E
	Weir et al. (2011)	Qual-3	Qualitative; used Clark's theory of communication to focus on one theme (communication and coordination) from prior study. Focus groups.	User experiences, collaboration, coordination	A, B, D, E
	Zadvinskis et al. (2014)	Qual-2	Qualitative, phenomenology. Interviews.	Nurses' perceptions of EHR and barcode medication administration	B, C

Note. EHR = electronic health record; MM = mixed-methods; MMAT = Mixed-Methods Appraisal Tool; NASA-TLX = NASA Task Load Index; Qual = qualitative; Quan = quantitative; RN = registered nurse; VS = vital signs.
*A = forming and maintaining overview of the patient; B = the cognitive work of navigating the EHR; C = the use of cognitive tools; D = forming and maintaining common ground and a shared understanding of the patient; E = the loss of information and professional domain knowledge.

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Sample, Setting	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Ammenwerth, E., Rauchegger, F., Ehlers, F., Hirsch, B., & Schaubmayr, C. (2011). Effect of a nursing information system on the quality of information processing in nursing: An evaluation study using the HIS-monitor instrument. *International Journal of Medical Informatics, 80*(1), 25-38.	Austria University Hospitals of Innsbruck, 13 inpatient units in final analysis 94 nurses from throughout hospital system	Assess impact of introduction of a computer-based nursing information system (NIS) on the quality of information processing in nursing: 1. How does the quality of information processing change after introduction of a NIS? 2. Explore expectations and fears before intro and were they fulfilled?	Mixed methods Quantitative: Adapted Health Information System (HIS)-monitor instrument from 107 to 41 questions considered nurse-focused. Added 10 general questions on overall satisfaction Survey during training and again a year later. Participants completing both surveys included in analysis 1st survey, N=179 2nd survey, N=130 Both surveys, N=94 Comparison using McNemar-Bowker-test, p .05 Qualitative: 2 open-ended questions focusing on expectations and fears of new system in 1st survey and perceived benefits and drawbacks in 2nd survey Analyzed free text via inductive content	Improvement in quality of information processing, support during anamnesis and care planning, availability, readability and completeness of nursing documentation, better overview of patient, reduction of duplicate documentation, workflow support with task lists and checklists. Mixed results with time related to nursing documentation Significant increase in perceived quality of information processing in 25 of 41 questions and unchanged in 16. No question with significant decrease in perceived quality Increase in areas related to efficiency, readability, information access, legal issues and re-usage of data Unchanged in areas related to communication with physicians, access to reports/images, support for prescriptions, handover, avoidance of double examinations 75% (69/94) nurses in 1st survey quite or very comfortable using computer; 93% (87/94) in 2nd survey Focused on free text with more than 20 responses, reported better overview	IRB approval and consent process not described Cronbach Alpha on subset of questions showed partly sufficient reliability w/some parts below .70. Cannot confirm validity of instrument Reported significant change in 25/41 questions, but in table, only 20 questions had p-value less than .05 Comments summarized and they analyzed themes where responses were >20. Outside of this criterion there were many negative comments with fewer responses having to do with loss of overview of patient, missing free text, nursing process not reproducible, system complexity, duplicate documentation.	Information processing Overview of patient Access to information Care planning, readability, documentation completeness Task lists, checklists Reduced duplication Time burden related to documentation	Health Information System (HIS) monitor Assessed comfort with computers

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Sample, Setting	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
			analysis using MaxQDA. Phrases identified and generalized into system of categories. Open-ended responses aggregated into 15 categories				

Note. BSN = bachelor of science in nursing; CPOE = computerized physician order entry; ED = emergency department; EHR = electronic health record; ICU = intensive care unit; IRB = institutional review board; IT = information technology; MS = medical surgical; NICU = neonatal intensive care unit; OH = Ohio; PI = principal investigator; RA = research assistant; UT = Utah; VA = veteran's administration; VS = vital signs; WA = Washington

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Chao, C.A. (2016). The impact of electronic health records on collaborative work routines: A narrative network analysis. *International Journal of Medical Informatics, 94, 100-111.*	U.S. Midwest community hospital Perinatal services department 26/29 nurses completed pre-survey (90%), and 21/27 completed post-survey (78%)	Examine collaborative work routines and changes after the implementation of a perinatal EHR Specific aims: 1. How were intra- and interdisciplinary communication and nursing documentation routines affected by introduction of EHR? 2. How did EHR affect standardization of these work routines? 3. What was the process of changes and the drivers underlying those changes in work routines?	Mixed methods case study, thematic analysis, network analysis, survey Qualitative: Pre-and post-implementation observations 6 months before and 6 & 9 months after. Took place over 18-month period totaling 90h of observations Focus was on work routines and intra- and interprofessional communication including 15 shift change meetings Formal and informal interviews with administrative and clinical staff, project meeting observations, artifact review, and field notes Workflow and narrative network analyses of work routines to identify changes pre- and post-EHR and to represent different perspectives of work routines Quantitative: Pre- and post-implementation survey asking nurses to rate frequency of communication around documentation processes and decision-making	Collaborative grounding via shift change report and informal communication Preemptive grounding via shift change report Informal communication for just-in-time grounding Increased use of personal notes after EHR Increased verbal communication to maintain common ground EHR improved documentation efficiency and in- and out-patient information exchange, but increased variability in documentation EHR support for clinician communication and coordination was limited EHR cognitive support insufficient, increased cognitive load by scattering information and lengthy printouts fragmented information and made its retrieval more difficult Increased frequency of verbal communication Increased use of cognitive artifacts (own forms and	Triangulation: observations, interviews, survey, network analysis Prolonged engagement and saturation Results difficult to track and would have helped to have a concise summary of findings IRB approval described, consent not described. Letter describing voluntary nature	Communication channels to create joint action Shared understanding of the situation Maintain common ground Negotiate responsibilities and coordinate actions Verbal communication commonly used because it requires low cognitive resources, other forms of communication using cognitive artifacts are common Patient information and clinical knowledge are distributed across the clinicians and artifacts	Researcher developed survey Observation, interviews, artifact review

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
			Statistical analysis of survey data related to changes in frequencies of communication	personal notes) after EHR Frustration over EHR-generated summary reports Functional properties of EHR focused on information aggregation, storage, and retrieval were at odds with extant culture and practice of healthcare emphasizing autonomy and flexibility			

Note. BSN = bachelor of science in nursing; CPOE = computerized physician order entry; ED = emergency department; EHR = electronic health record; ICU = intensive care unit; IRB = institutional review board; IT = information technology; MS = medical surgical; NICU = neonatal intensive care unit; OH = Ohio; PI = principal investigator; RA = research assistant; UT = Utah; VA = veteran's administration; VS = vital signs; WA = Washington

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Colligan, L., Potts, H. W., Finn, C. T., & Sinkin, R. A. (2015). Cognitive workload changes for nurses transitioning from a legacy system with paper documentation to a commercial electronic health record. *International Journal of Medical Informatics, 84*(7), 469-476.	U.S. (Assume this because first author affiliated with U.S. hospital, not explicit in report). 131-bed children's hospital within an academic tertiary system 74 nurses from inpatient pediatric units or NICU Census sampling: All available nurses working during 2-week period one month before EHR implementation Same 74 nurses administered survey at other intervals No nurses dropped out but complete data (no shift missed) obtained for 63 (82%) of nurses	Assess the changes in cognitive workload among pediatric nurses during data entry and retrieval tasks during transition from a hybrid electronic/paper system to a commercial EHR	Quantitative descriptive Baseline computer attitude and skills scores NASA Task Load Index (NASA-TLX) used to measure cognitive workload during data entry and retrieval tasks NASA-TLX administered pre-implementation and at 1, 5, 10 shifts and 4 months post-implementation of EHR Two other instruments used pre-implementation to measure attitudes and computer skill: Computer Attitude Score, and Computer Understanding and Experience Scale Two trained researchers administered instruments and tracked schedules of nurses to coordinate data collection at designated shifts Completed NASA-TLX at end of 12-hr shift, one for data entry and one for retrieval. 6 subscales for	Substantial increase in cognitive workload at shifts 1 and 5 (above 15%) Increased cognitive workload returned to baseline for most participants by 10 shifts but there was considerable variation in transition to new EHR Key predictor of fast adaptation was a positive computer attitudes score Effect observed from computer skills and age but these were mediated by the computer attitudes score	Appropriate statistical analysis No control group because all nurses used new EHR Used other measures related to computer attitudes for context Limited to implementation period and did not look at complexity of EHR implementation and use, or how clinicians viewed EHR NASA-TLX limited breadth and depth related to cognitive work Looked at only two tasks which may not have captured breadth of complexity of human-IT interaction	Cognitive workload Increases after implementation but resolves 15% threshold for NASA-TLX in other high hazard domains	NASA-TLX Computer Attitude Score, and Computer Understanding and Experience Scale

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
			each survey x2 = 12 subscales Average of the 12 subscores at each of 5 administrations				

Note. BSN = bachelor of science in nursing; CPOE = computerized physician order entry; ED = emergency department; EHR = electronic health record; ICU = intensive care unit; IRB = institutional review board; IT = information technology; MS = medical surgical; NICU = neonatal intensive care unit; OH = Ohio; PI = principal investigator; RA = research assistant; UT = Utah; VA = veteran's administration; VS = vital signs; WA = Washington

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Collins, S. A., Bakken, S., Vawdrey, D. K., Coiera, E., & Currie, L. (2011). Model development for EHR interdisciplinary information exchange of ICU common goals. *International Journal of Medical Informatics, 80*(8), e141-149.	U.S. Large urban teaching hospital 18-bed neurovascular ICU Neuro ICU nurses and physicians Commercial EHR for nurse and physician documentation	To categorize the types of communication and information activities that occur during interdisciplinary communication of ICU common goals in the context of EHR use and develop a theoretical model of interdisciplinary information exchange of ICU common goals in context of EHR use	Qualitative Theoretical frameworks: Coiera's clinical communication space and distributed cognition Ethnographic observation, focus groups and interviews to identify and analyze goal-directed actions and interactions related to interdisciplinary communication of common goals in the ICU Observations during morning interdisciplinary rounds. 59.5 h of interdisciplinary rounds, 5 interviews with key informants (1 nurse, 4 residents), 1 focus group with 8 nurses Frameworks were used to analyze and map data	EHR was observed and perceived by clinicians to be insufficient for the capture of interdisciplinary information exchange of common goals and this may have resulted in increased clinician reliance on verbal communication Observed nurses' autonomy and decision-making in action, yet found that those actions and decision-making were not reflected in the EHR. This lack of visibility of autonomous actions and decision-making may impede understanding of patient care processes and outcomes that make care more efficient, effective, and safe EHR information retrieval inefficient compared to verbal exchange or paper-based notes (personal notes, to-do lists, print outs from EHR) EHR not sufficient for collaborative decision-making EHRs should support information	Strengths: combining the two frameworks created perspective beyond individual cognitive processes to include artifacts, information flow at the individual level and action and interactions within the clinical unit Used multiple methods of data collection Prolonged engagement, member checking during focus group and interviews, data saturation Limitations: Number of interviews and focus groups may have been insufficient. Observations done on day shift only. Not clear who did the data collection and analysis. No discussion of positionality	EHR insufficient for information retrieval and collaborative decision-making Nurses' autonomous decision-making not represented in the EHR Distributed cognition. Hazelhurst 6 categories of verbal information exchange	Focus groups, interviews, observation

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
				tools for goal, intervention, and assessment documentation and messaging tools for collaborative decision-making and patient-safety communication			

Note. BSN = bachelor of science in nursing; CPOE = computerized physician order entry; ED = emergency department; EHR = electronic health record; ICU = intensive care unit; IRB = institutional review board; IT = information technology; MS = medical surgical; NICU = neonatal intensive care unit; OH = Ohio; PI = principal investigator; RA = research assistant; UT = Utah; VA = veteran's administration; VS = vital signs; WA = Washington

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Darbyshire, P. (2004). 'Rage against the machine?': Nurses' and midwives' experiences of using computerized patient information systems for clinical information. *Journal of Clinical Nursing, 13*(1), 17-25.	Australia 25 different practice settings in 5 capital cities and one regional center in Australia 53 nurses and midwives	Explore clinical nurses' and midwives' perspectives and understandings of computerized patient information systems (CPIS) in everyday practice Gain a deeper understanding of nurses' and midwives' experiences using CPIS and explore their meanings, perceptions and understandings concerning CPIS. Investigate their perspectives of CPIS impact on patient care, clinical practice, and outcomes	Qualitative Interpretive phenomenology 13 focus groups lasting 45-90 minutes Open ended questions Researcher didn't have experience with CPIS so informants were asked to describe in detail how systems were used, etc. Concurrent data collection and analysis. Data analyzed line by line for themes, patterns, events, perceptions, understandings and practices regarding informants' experiences using CPIS	Positive: reduced administrative or repetitive tasks, improved legibility, less work creating forms and entering data Negative: CPIS perceived as a management or administrative tool versus a clinical tool Short-changed nursing because it was incapable of capturing crucial elements of nursing care. Trying to fit a complex caring practice into systems incapable of capturing this, reflected partial view of practice Clinically relevant information retrieval difficult CPIS across locations don't interface so information is lost	Strengths: Wide range of practice settings, large sample Limitations: Findings were mostly descriptive, superficial analysis and data elements in the manuscript were weak. Lacked thick description Did not include high-level synthesis of findings or context Tone of the writing seemed exaggerated and negatively biased Only one data collection method. Little discussion regarding rigor	Improved legibility Reduction in administrative and repetitive tasks Administrative tool versus clinical Does not capture nurses work, partial view of practice Clinically relevant information retrieval difficult Information loss due to interface issues across locations	Focus groups

Note. BSN = bachelor of science in nursing; CPOE = computerized physician order entry; ED = emergency department; EHR = electronic health record; ICU = intensive care unit; IRB = institutional review board; IT = information technology; MS = medical surgical; NICU = neonatal intensive care unit; OH = Ohio; PI = principal investigator; RA = research assistant; UT = Utah; VA = veteran's administration; VS = vital signs; WA = Washington

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Embi, P. J., Weir, C., Efthimiadis, E. N., Thielke, S. M., Hedeen, A. N., & Hammond, K. W. (2013). Computerized provider documentation: Findings and implications of a multisite study of clinicians and administrators. *Journal of the American Medical Informatics Association, 20*(4), 718-726.	U.S. 5 VA medical centers in WA, OH, UT Sites of varying size, complexity and geographic location VA employees with at least 2 years' experience using the system. 54 physicians or practitioners, 34 nurses, and 37 administrators All sites had used the VA EHR system for over 10 years	Study the impact of computerized provider documentation (CPD) on multiple stakeholders in various settings, aiming to capture viewpoints of both clinicians and administrators and identify higher-order themes related to working with CPD	Qualitative 3 focus groups (one for each stakeholder group) at each site with the exception of one site for total of 14 focus groups Recruitment via email. Inpatient and outpatient nurses and licensed practical nurses 2 investigators conducted 1h focus groups at each site Standard semi-structured interview guide Goal of each focus group was to elicit views/perceptions about using CPD in everyday practice 6 investigators participated in multiple rounds of analysis. Final codes by two investigators, then all investigators coded Final review reconciled discrepancies and yielded codes, sub-codes, and relationships Summary interpretations drawn from categorizations organized into common themes. Reached saturation by 3rd site with few if any new codes from last two sites	5 themes: communication and coordination; control and limitations of expressivity; information availability and reasoning support; workflow alteration and disruption; and trust and confidence concerns EHR insufficient for care coordination, reduced direct clinician communication, tasks and problems difficult to track and to reconstruct events and details across multiple problems and encounters Burdensome to discern major issues and goals of care, difficult to summarize information for transfer or handoff Information excessive, forced duplicative charting, template-constrained language diminished clinical usefulness of information, less informative than free text Ease of retrieval and cognitive usefulness mixed:	Strengths: Multisite and various perspectives, 14 focus groups. 1 researcher led focus groups to ensure consistency across sites, all 6 investigators participated in data analysis and synthesis. Reached saturation, resolved discrepancies in interpretations Semi-structured interviews using an interview Separated stakeholder groups in order to encourage sharing and minimize conformity pressures Limitations: Single EHR that had been in use for a long time may limit generalizability of findings VA system has different reimbursement pressures Focus groups subject to conformity pressures Single data collection method	Care coordination Reduced communication Difficult to track and understand clinical course and reasoning Did not define overview, but implied difficult to obtain overview Did not facilitate handover Documentation completeness at expense of meaningful information Cognitive overload from complexity and volume of information Did not match nurses flow of work and continuous data collection Paper persistence: Nurses continued using notes to manage information	Focus groups

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				improved availability of information and asynchronous access, but information cluttered with irrelevant text, hard to search across documents, read fewer notes. Information unorganized, difficult to decipher clinical reasoning for orders and to determine symptom patterns and disease course Templates, data completeness interfered with reconstructing the flow of care Nurses' mobile, team-based work, duplicate documentation, and summarizing care in shift notes clashed with nurses' need to collect data continuously. Carried paper notes to manage information. Relied on verbal exchange to augment Pressure to document care for reimbursement produced messy, process of inserting data that could be misleading, sometimes data not current, created lack of trust in data			

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				accuracy in the record			

Note. BSN = bachelor of science in nursing; CPOE = computerized physician order entry; ED = emergency department; EHR = electronic health record; ICU = intensive care unit; IRB = institutional review board; IT = information technology; MS = medical surgical; NICU = neonatal intensive care unit; OH = Ohio; PI = principal investigator; RA = research assistant; UT = Utah; VA = veteran's administration; VS = vital signs; WA = Washington

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Keenan, G., Yakel, E., Dunn Lopez, K., Tschannen, D., & Ford, Y. B. (2013). Challenges to nurses' efforts of retrieving, documenting, and communicating patient care information. *Journal of the American Medical Informatics Association*, *20*(2), 245-251.	U.S. 8 MS units in 4 diverse hospital settings in a Midwestern state 1 large teaching, 2 large community, 1 small community N=20 nurses Used a revised Benner novice-expert definition (collapsed categories) to guide sampling (9 novice, 11 expert) All nurses invited to participate did so	Describe existing nursing practices that affect information management and flow Identify potential sources of error and opportunities for systematic improvement	Qualitative Content and thematic analysis 200h ethnographic observations of nurses' communication patterns, documentation and care planning during entire shift (8 and 12h). Observations on every shift on every unit Analyzed nurse-designed communication artifacts Observations began at handoff and ended with an interview at end of each shift observation Interviews with a nurse manager from each unit prior to observations to understand context and processes. Did not include in analysis, differed from real practice Data from observations entered into spreadsheet, also created a narrative of each observation Content analysis of interview, observation,	3 common themes Variation in nurse documentation and communication Absence of a centralized care overview in the patient's electronic health record Rarity of interdisciplinary communication Wide variation in nurse documentation and communication practices in use of paper, balance of paper versus electronic documentation and handoff practices. Heavy reliance on paper even in presence of robust EHR. Paper included handmade forms, outputs from EHR, scraps, post it notes. EHRs did not support nurses' need for organized and synthesized overview of their patients' status and care needs Duplication and redundancy were an accepted part of everyday work	Maximum variation sampling strategies at hospital, unit, nurse levels Standardized protocol observation forms Trained research assistants did observations and interviews Data analyzed by one researcher and reviewed by 2nd until consensus Prolonged engagement, triangulation, peer debriefing. Coding reviewed by PIs and RAs until consensus, audit trail Thick narrative descriptions of observations synthesized and used for context Collapsed Benner criteria based on years' experience may not have reflected novice-expert No discussion of PI or RA positionality during data collection or analysis Varying levels of EHR adoption/implementation in each hospital	Absence of centralized care overview Rarity of interdisciplinary communication Variation in use of paper, types of paper (EHR versus handmade), all used some type of handmade notes Patient overview forms homemade and not part of EHR Nurses consolidated and interpreted information from variety of sources and disciplines to coordinate care without seeking validation Information exchange during interdisciplinary communication rarely documented Duplication and redundancy	Observations Interviews Artifacts analysis

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			and artifact data				

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Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Kossman, S. P., Bonney, L. A., & Kim, M. J. (2013). Electronic health record tools' support of nurses' clinical judgment and team communication. *Computers, Informatics, Nursing, 31*(11), 539-544.	U. S. ICU and MS units in a Midwest tertiary hospital 50 nurses, 46 responses to survey, 33 (72%) completed it and were included in analysis 4 nurses participated in focus group Total N=37 Nurses with more than 6 months experience with EHR	Explore impact of use of self-made and EHR-generated cognitive artifacts (CAs) on clinical judgment and team communication 3 aims: 1. What CAs do nurses use to support their clinical judgment and team communication 2. Nurses' perceptions of utility of selected CAs for support of clinical judgment and team communication 3. How often do nurses and others use these CAs in patient care	Descriptive, convergent mixed-method design Online survey and/or focus group interviews Online survey developed by research team asked Nurses to rate frequency of use and utility of 7 CAs on clinical judgment and team communication These were: self-made work lists, EHR problem list, focused assessment forms, clinical practice guidelines, care plan, medication administration record (MAR), and summary note Also rated CAs based on attributes reflecting the dimensions of clinical judgment: noticing, interpreting, responding, and reflecting using a 5-point scale from extremely helpful to do not use Focus group interviews and open-ended questions probed nurses about CAs they use and how they could be redesigned to	Most nurses used all CAs at least once daily and found them helpful in supporting overall clinical judgement (except for problem list) and team communication (except for care plan) but rated self-made work lists as more helpful than any EHR tool except for the MAR Nurses rated self-made work lists and the MAR as the most helpful CA Statistical analysis verified the significant association between these tools and communication, clinical judgement and 3 of its dimensions (noticing, interpreting and responding) Improvised work lists and EHR tools varied in their utility to support specific clinical judgement attributes Most nurses rated none of the CAs as ''extremely helpful'' to key pieces of nursing work such as anticipating potential complications	Strengths: Survey based on Tanner's clinical judgment model and Lasater's operationalization of its 4 dimensions. Make sense for research question and offered concrete examples of nurses' work Triangulation of data Rigorous statistical analysis looked not only at usage and perceptions but also tested for association of scores of clinical judgement and communication and 4 dimensions with tools; post hoc analysis to identify which CAs contributed to significance Limitations: Single focus group of only 4 nurses; limited qualitative data analysis; no observations 33/46 nurses completed survey or 13 didn't complete in entirety. Remarked on in limitations and need for survey revision to explore if too long and to clarify definitions of tools	Cognitive artifacts Clinical judgment Communication Noticing, responding, interpreting Organization and display of EHR tools don't support cognitive work Nurses preferred self-made cognitive artifacts over EHR-generated tools	Survey, focus groups, interviews, EHR usage

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			better support work Analyzed EHR usage statistics to identify usage trends by RN, physician, therapists, pharmacists, social workers, & pastors Descriptive and inferential statistics Content analysis for identification of themes	and making sense of patient data (aspects of interpreting) and evaluating care through determining if the patient met outcomes and adjusting treatment to achieve goals (aspects of reflecting) Organization or display of information on these tools is not supporting important aspects of nursing work Nurses rated their improvised CAs more useful for overall clinical judgment and communication than any EHR tools except the MAR. Organization and display of information on improvised tools aid workflow by prompting memory and highlighting needed information in an easily accessible place			

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Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Kossman, S. P., & Scheidenhelm, S. L. (2008). Nurses' perceptions of the impact of electronic health records on work and patient outcomes. *Computers, Informatics, Nursing, 26*(2), 69-77.	U.S. MS and ICU unit at 2 community hospitals 46 nurses (50%) response rate Hospital 1: 31 nurses completed 29 surveys and 15 interviews observations Hospital 2: 15 nurses completed 13 surveys and 7 interviews observations Convenience sample of nurses with at least 6 months experience using EHR	To describe how community hospital nurses use EHRs as they provide care and their views of the impact of EHR use on their work and patient outcomes	Qualitative Descriptive Based on phenomenological principles Questionnaire survey using open-ended questions to explore phenomenon Researcher observed nurses on units using EHRs and concurrently interviewed them to observe practice patterns, problems with EHR use, workarounds Demographic questionnaire included question about comfort with technology	Enhanced nursing work through increased information access, improved organization and efficiency, and alert screens Hindered nursing work through increased documentation time (slow system response, multiple screens), decreased interdisciplinary communication and impaired critical thinking through overuse of checkboxes and copy and paste documentation Decreased time with patient Checkboxes not matching the work or the clinical situation and so documentation not done or not accurate Increased ease and access to information for clinical decision-making and better organization of information and tasks Doctors and nurses not reading notes limiting team communication. This was due to physicians not knowing where	Strengths: Triangulation; Emerging themes influenced future questions and observations: Sought to clarify, validate, refute Data quotes supported findings Limitations: Physician use of the EHR and CPOE was inconsistent; hence unclear how this impacted culture, interactions with nurses Sample overrepresented younger nurses (median age 35) and bachelor's prepared nurses (55%), which is not reflective of nation EHR acceptance assessed via a question that asked how you'd feel if EHR went down. Concluded negative responses indicated EHR acceptance. May have reflected nurses' concern about loss of information instead of acceptance.	Increased information access, improved organization and efficiency, alert screens helpful Increased documentation time Decreased interdisciplinary communication Impaired critical thinking through overuse of checkboxes and copy and paste documentation Increased ease and access to information for clinical decision-making and better organization of information and tasks Notes not viewed or read by physicians	Survey, observation, interviews

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				to find them, inconsistency of where they are, difficulty getting to them			

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Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Schenk, E. C., Mayer, D. M., Ward-Barney, E., Estill, P., Goss, L., & Shreffler-Grant, J. (2016). RN Perceptions of a Newly Adopted Electronic Health Record. *Journal of Nursing Administration, 46*(3), 139-145.	U.S. 250-bed regional tertiary hospital Convenience sample. 420 acute care nurses invited, 285 participated 131 pre-implementation survey (31%); 154 post-survey (37%) 11 pre-implementation interviews, 10 post (same nurses)	Understand nurses' perceptions of a newly adopted EHR	Mixed methods based on the conceptual framework, the technology acceptance model (TAM). Modified an existing 11-item survey used to measure perceptions of e-learning - adapted to reflect EHR perceptions re: ease of use, usefulness and attitudes t-tests for each sample (not matched) Electronic survey 4-8 weeks before and 8-12 months after EHR implementation Small subset or nurses interviewed Qualitative data: Analyzed for patterns, compared to transcripts to seek consensus and identify themes Researchers worked independently then met together to discuss interpretations until consensus reached Several questions in demographic survey asked about computer proficiency, experience with EHR	Quantitative: 8 of 11 questions significant difference post-implementation Less favorable for 2 of 4 questions in ease of use domain, all questions in usefulness domain, and 3 of 4 in the attitude domain Half of nurses reported being proficient with EHR Qualitative: Although EHR offered a holistic view of the patient, information was fragmented and complex and created workflow challenges What is needed to do nursing work not built into the EHR Data in EHR overly complex Abnormal diagnostic findings difficult to access leading to overlooked information and missed communication	Strengths: Mixed methods Context for quantitative findings understood via qualitative data Immersion, peer debriefing, member checking. Independent and then group discussions re: interpretations of data, reached consensus Reasonable amount of time for post-survey Limitations: Modified instrument evaluated by content experts in informatics and nursing but not validated No clear detail about methods used for qualitative data analysis Low response rate to survey	Less favorable post-implementation for ease of use, usefulness, attitudes Fragmented information Data overly complex Workflow challenges Nursing work not accommodated	Survey, modified existing instrument used for e-learning interviews

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Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Staggers, N., Clark, L., Blaz, J. W., & Kapsandoy, S. (2012). Nurses' information management and use of electronic tools during acute care handoffs. *Western Journal of Nursing Research, 34*(2), 153-173.	U.S. Two western institutions: academic 425-bed med center (2 surgical and one medical unit) and a 50-bed oncology specialty hospital Purposive sampling across expertise, employment status, shift type and length Nurses with less than 6 months experience excluded 26 nurses giving report	To examine nurses' information management before and during handoffs on MS units in settings with computerized physician order entry and electronic documentation	Qualitative Interpretive descriptive Nurses contacted via email by researchers, consent in person Data collection on 25 occasions, 93 handoffs, 5 different units over 2-month period Focus was on nurses giving report. 4 types of data collection: audio recorded handoff at end of shift, field observation with field notes integrated into transcript data; semistructured debriefing interview with each nurse giving report probing about handoff practices and tools used; handoff tools/forms blinded Transcribed data coded descriptively, inductive coding by team on first 6 of 25 documents to reach consensus about coding manual and meanings. Thereafter worked independently	5 themes, 33 categories Themes captured dimensions of handoff, info needed and how managed before and during handoff. Qualities of successful handoff. In context of unit culture and expectations, definitions of what a good nurse is and a good/useful handoff No nurses used available electronic handoff tool or the EHR as main source of information for handoff. EHR was used to augment or verify information on their handoff tools. Defended use of paper forms EHR forms did not provide important information and arbitrarily truncated data. Did not put information in context, or help them fulfill their expectation of a good nurse All 26 nurses relied on a paper form instead of using the EHR summary. 65% used own summary, 35% used EHR generated, added info to it or customized it. Spatially	Strengths: Prolonged engagement, triangulation, rigorous analysis process with all researchers engaged, thick description, and findings make sense for context and purpose of study Team debriefings to clarify perspectives Observation of shift change Limitations: Single EHR vendor but widely used	EHR tools: Do not support nurses as they synthesize, organize and understand information Do not provide easily accessible at-a-glance information Do not match nurses work, having something to carry with during shift and add to as they care for patient important for putting together information needed for handoff The tailored forms represent synthesized information across sources, tools, patients and other nurses' communication tailored to this patient, this shift, and this unit. This kind of synthesized information was unavailable from the EHR Tailored tools facilitated clinical judgment	Observation interviews artifacts review

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Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
			Regular team meetings to share analysis. Inter-coder reliability on 2 transcripts Theoretical and axial coding to identify categories and properties Recursive 1st and 2nd level coding	organized the paper as they planned care and created a way to track pending and completed work Paper tools used to synthesize information. Physically writing information helped nurses' thinking process, to remember, encode, cement, synthesize info Benefit seen in EHR form was not writing certain info. More nurses on surgical transplant unit used EHR form and MS units used least Content of forms tailored to make info immediately retrievable Rely on tools outside the EHR to support cognitive work during handoff. Personal forms helped them prioritize, organize, prioritize, encode, update crucial information throughout shift and during handoff			

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Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Staggers, N., Clark, L., Blaz, J. W., & Kapsandoy, S. (2011). Why patient summaries in electronic health records do not provide the cognitive support necessary for nurses' handoffs on medical and surgical units: insights from interviews and observations. *Health Informatics Journal, 17*(3), 209-223.	U.S. Two western institutions: academic 425-bed med center (2 surgical and one medical unit) and a 50-bed oncology specialty hospital Purposive sampling across expertise, employment status, shift type and length Nurses with less than 6 mo. experience excluded 26 nurses giving report	To understand how acute care nurses used electronic patient summary reports or EHRs during handoffs	Qualitative Interpretive, descriptive. Data collected on 25 occasions, 93 handoffs, 26 nurses giving report on an average of 4 patients during 8 or 12h shifts Observations and interviews during handoff focused on nurses giving report based on idea that cognitive work different when giving Taped handoff, conducted observations, field notes of unit environment, 2 observers: one captured context of report and other recorded specific EHR screens used. Average 40 min for observations Semi-structured questions after giving report, 30 min, focused on how they prepare, tools used, if not EHR-generated, why? Probed how they prepared and tools used Interviews analyzed to understand nurses use of the computerized summary during handoff using conventional content analysis techniques	Of 26 nurses, 17 used personal forms and 9 used EHR-generated reports All forms had additional info written on them. Used the forms throughout the shift and called them their brains. Despite being encouraged to use EHR-generated summaries, nurses did not use and if they did they augmented them because they were seen as incomplete. Sequence of information did not match how nurses need to see or process information, making information difficult to find Ability to take notes on form seen as critical. Did not match the way they work or think. Lacked overview (e.g. VS trends) and integration (e.g. seeing meds with VS, labs with meds). Lacked portability and at a glance information. EHR summary eliminates act of writing, which nurses used to encode, remember, organize and prioritize information across patients Nurses on one surgical transplant unit used EHR summary the most. Interviews revealed they did not have to capture same level of detail like demographics. Medical units used least, needed more complex information to manage patients Nurses with more experience had most difficulty with EHR summary. Nurses used the initial handoff report throughout the shift, and needed tool to match their work and how they process and synthesize information	Strengths: Triangulation, rigor in analysis by peer debriefing, member checking. Good synthesis of findings from different sources of data. Limitations: Specialized surgical unit, oncology hospital may not be representative of all nurses. Vendor supported EHR, which may have biased results	EHR-generated tools insufficient for nurses cognitive and practical workflow Sequence of information did not match how nurses need to see or process information making info difficult to find Process of writing important for thinking and synthesizing EHR forms lacked overview (trends) and integration of crucial information Not portable and did not provide information at a glance Different units have different needs Experience affects acceptance of EHR tool	Observation interviews artifacts

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			Observation data as field notes and interview data analyzed together. Individually and as a group. First 6 analyzed together to develop coding manual				

Note. BSN = bachelor of science in nursing; CPOE = computerized physician order entry; ED = emergency department; EHR = electronic health record; ICU = intensive care unit; IRB = institutional review board; IT = information technology; MS = medical surgical; NICU = neonatal intensive care unit; OH = Ohio; PI = principal investigator; RA = research assistant; UT = Utah; VA = veteran's administration; VS = vital signs; WA = Washington

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Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Stevenson, J. E., & Nilsson, G. (2012). Nurses' perceptions of an electronic patient record from a patient safety perspective: a qualitative study. *Journal of Advanced Nursing, 68*(3), 667-676.	Sweden District general hospital Convenience sample Recruitment in 6 MS wards, 21 nurses from 3 of the units participated Included surgical, medical, orthopedics	Explore nurses' perceptions of using electronic patient records (EPRs) in everyday practice in general ward settings	Qualitative 4 focus groups Content analysis Data collected over 2 weeks EHR in place for one year 4 focus groups lasting 50-80 minutes. 2 researchers conducted groups. Did not structure interview guide to encourage free flow of information. One opening question: what are your experiences of using the EPR in every day work? Both researchers participated in analysis, came to consensus on categories and sub-categories	Main category: documentation in everyday practice. Subcategories: VS, overview, medication module Information about VSs difficult to enter and locate in EHR Positive and negative data regarding overview of the patient: Nurses could access EHR simultaneously and allowed multiple users. All data was in the record. Difficult to obtain an overview of the patient, complex processes taking too much time to find out about the patient. Could not obtain a view of the patient's progress This loss of overview caused them to go back to verbal reports Importance of using their experience and clinical judgment when meeting patient for 1st time but didn't support with any meaningful data elements to support this reported finding Medication module: could not see updates	Strengths: Member checking, peer debriefing, both researchers did interviews and analysis, took findings to a separate group of 15 nurses in other hospitals and they felt data was true to their experience Limitations: Nurses used the EHR more comprehensively than other stakeholders for documentation, templates and report sheets. Other users only had access to one narrative notes area. May have affected overview. Single hospital in Sweden 2 weeks of data collection	Difficult to enter and locate information Simultaneous access positive Difficult to obtain overview and progress, caused them to go back to verbal reports Complex processes taking too long to learn about patient Need to use experience and clinical judgment when interacting with patient for first time Could not see medication updates	Focus groups

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Varpio, L., Rashotte, J., Day, K., King, J., Kuziemsky, C., & Parush, A. (2015). The EHR and building the patient's story: A qualitative investigation of how EHR use obstructs a vital clinical activity. *International Journal of Medical Informatics, 84*(12), 1019-1028.	Canada 167-bed pediatric tertiary center 354 total participants including 22 patients, 32 parents, 40 physicians, 66 residents, 11 medical students, 121 nurses, and 62 allied health professionals 60 staff participated in both data collections Purposive sample of wide range of clinicians and levels of expertise	To investigate the impact of implementing and EHR on the documentation and care practices of individual clinicians and clinician teams	Qualitative Constructivist grounded theory 146h of non-participant field observations, 39 individual semi-structured interviews (patients, families, clinicians), document analysis (392), and think-aloud (13) and think-after (11) sessions of clinicians when engaged with the EHR to build patient's story Iterative data collection and analysis, vital clinical activity of building the patient's (BPS) emerged as a central theme. Developed 6 interrelated questions to explore participants' views about the meaning, process and significance of BPS. Data collected before and after implementation of EHR Followed 10 patients pre-implementation and 12 patients post-implementation from Pediatric ICU to discharge. Collected all patient-related communication used by	BPS was a vital clinical skill that is destabilized with EHR use Clinicians described the patient's story as a summative understanding or cognitive awareness and overview understanding of the patient's (1) current status, (2) relevant history, (3) data patterns that emerged during care, and (4) the future-oriented care plan. Constructed by consolidating and interpreting a wide array of patient data derived from interactions with patients and colleagues), the medical record, assessments BPS was described as a vitally important skill that was required to provide patient-centered care, within an interprofessional team, that safeguards patient safety and clinicians' professional credibility EHR use obstructed clinicians' ability to build the patient's story by fragmenting data interconnections. Limited free text space for notes inhibited clinicians' ability to decipher and interpret clinical activities from	Strengths: Sustained and varied exposure to the phenomenon via 4 data collection approaches. Concurrent data collection and analysis. Deep engagement with the data and the literature as themes emerged. All 6 researchers participated in analysis. Member checking with stakeholders verified findings. Rich data elements supported the authors' interpretations. Collected additional data to vet themes until saturation was achieved. Audit trail via Study CV format. Limitations: One pediatric tertiary center. Did not address researcher positionality or any issues that arose in the field during data collection or analysis	Building the patient's story Overview Cognitive awareness, overview, understanding the patient's current status, relevant history, data patters, future oriented care plan Ability to consolidate and interpret a wide array of data derived from interactions, the medical record, observations and assessments Fragmented data interconnections Time consuming to construct BPS	Observation interviews document analysis Think-out-loud and think-after sessions

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			clinicians to respond to patient's needs. Purposively sampled patients needing collaboration from 3 or more professions over extended periods to maximize exposure to range of communication	other team members. This resulted in the loss of shared interprofessional understanding of the patient's story, and increased time required to build the patient's story			

Note. BSN = bachelor of science in nursing; CPOE = computerized physician order entry; ED = emergency department; EHR = electronic health record; ICU = intensive care unit; IRB = institutional review board; IT = information technology; MS = medical surgical; NICU = neonatal intensive care unit; OH = Ohio; PI = principal investigator; RA = research assistant; UT = Utah; VA = veteran's administration; VS = vital signs; WA = Washington

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Vikkelsø, S. (2005). Subtle redistribution of work, attention and risks: Electronic patient records and organisational consequences. Scandinavian *Journal of Information Systems, 17*(1), 1-28.	Denmark Medical ward consisting of multiple units in a 189-bed hospital 4 physicians, 4 nurses and 3 secretaries Purposive sampling of nurses on 3 shifts to capture range of work practices	Explore the way in which the introduction of an EHR affected the medical practice in a hospital ward	Qualitative Grounded theory, actor network theory Field observations with detailed field notes, analyzed documents and artifacts, photos of workspaces. Structured individual interviews Researcher created elaborate description of basic workflows and asked participants to read and reflect on whether the descriptions were typical, exotic or special cases and to define how such processes were before EHR Interviewed each person after they read description and gathered their responses then created description of earlier processes to compare ways tasks completed before and after EHR No detail on analysis process or explanation of rigor, how he arrived at	Redistribution of work and responsibility, organizational attention and risks reflected in changes in 4 aspects of daily work: writing and reading of progress notes, updating and reporting routines of the nurses, distribution of test results, and the medication process Findings related to nurses' cognitive work: Redistribution of work and responsibility Nurses became active readers and commentators of physicians work and spent more time entering and reading notes, less time on oral report and collective discussions Changed the way handoff was done, less interactive, more focused on computer Test results process significantly changed from linear daily sorting and alerting process to random results led to dilemmas regarding how work was structured, stronger attention to abnormal results, while all tests in system some may be overlooked Medication process changed to physician entering orders Creation of overview takes more work and done	Strengths: Science and technology study using actor network theory novel approach to problem adds valuable information and framework. Triangulation, prolonged engagement w/90h of observations Limitations: This EHR may not be typical for U.S. comparisons, seemed to be based more on a folder type layout Did not elaborate on processes during analysis, how rigor was maintained, and no mention of positionality Single cluster of units in a single hospital, very small sample	Nurses more engaged in physicians' work, more time entering and reading notes, less time on verbal report and interactive discussion Way handoff was done changed, less interactive and more focused on computer Tests results process more random, less systematic, prone to missing results Creation of overview takes more time and done informally by nurses	Interview observation,artifacts, photos

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
			conclusions. All findings framed in context of theory of distribution versus typical focus on improvement	informally by nurses Organizational attention: stronger focus on medical aspects of care and documentation, weaker focus on patient involvement, ethical and psychosocial			

Note. BSN = bachelor of science in nursing; CPOE = computerized physician order entry; ED = emergency department; EHR = electronic health record; ICU = intensive care unit; IRB = institutional review board; IT = information technology; MS = medical surgical; NICU = neonatal intensive care unit; OH = Ohio; PI = principal investigator; RA = research assistant; UT = Utah; VA = veteran's administration; VS = vital signs; WA = Washington

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Ward, M. M., Vartak, S., Schwichtenberg, T., & Wakefield, D. S. (2011). Nurses' perceptions of how clinical information system implementation affects workflow and patient care. *Computers, Informatics, Nursing, 29*(9), 502-511.	U.S. 300-bed Midwestern rural referral hospital Survey offered to all staff attending training on new clinical information system (CIS) with 1395 total respondents Half of respondents were nurses and licensed practical nurses (n=705). Did not identify ratio of nurses to licensed practical nurse Pre-implementation (N=354) After CIS training (N=203) 6 months post-implementation (N=148)	To examine the impact of a clinical information system implementation on nurses' perceptions of workflow and patient care throughout the implementation process	Quantitative descriptive Information Systems Expectations and Experiences (I-SEE) survey developed by researchers. 47-item survey designed to assess expectations and experiences before and after implementation. 7 scales at 3 levels: provider-patient, inter-provider-, and inter-organizational communication. Scales: work-life changes, improved care, support and resources, and patient care processes Survey administered 3 times: first day of training on new system, after training, and 6 months post-implementation	Responses more positive at 1st administration. Declined in subsequent data points. 8 of 47 item responses decreased significantly from 1st to 2nd and 37 of 47 items decreased significantly from 2nd to 3rd Compared results based on years' experience with EHR and in healthcare Factorial analysis of variance was used to compare mean responses across the 3 administrations and across groups of nurses with and without EHR experience Questions of interest for this review are access to information improving my ability to make good patient care decisions; communication at end of shift handoff, and, the new clinical information system will improve our ability to give patient care with the right information. All had statistically significant	Strengths: Validated instrument with Chronbach's alpha of >.70 for all scales Limitations: Single site response rates not reported, declined from 354 - 203 - 148. Said all nurses completed first survey, but this is not logical that they employed 354 Nurses for 300 staffed beds. May have optimistically reported results, discussion not consistent with tables	Access to information to make good patient care decisions Communication at end of shift Accuracy of information informing patient care	I-SEE survey

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
				declines from pre/post training to 6 months post-implementation			

Note. BSN = bachelor of science in nursing; CPOE = computerized physician order entry; ED = emergency department; EHR = electronic health record; ICU = intensive care unit; IRB = institutional review board; IT = information technology; MS = medical surgical; NICU = neonatal intensive care unit; OH = Ohio; PI = principal investigator; RA = research assistant; UT = Utah; VA = veteran's administration; VS = vital signs; WA = Washington

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Weir, C. R., Hammond, K. W., Embi, P. J., Efthimiadis, E. N., Thielke, S. M., & Hedeen, A. N. (2011). An exploration of the impact of computerized patient documentation on clinical collaboration. *International Journal of Medical Informatics, 80*(8)	U.S. 4 VA sites Staff volunteers from nursing, medicine and administration in all clinical areas, ED, ICU, primary care All participants had 2 years' experience using computerized provider documentation (CPD) N=116	Explore the experience of experienced computerized patient documentation (CPD) users for purpose of collaboration and coordination	Qualitative Separate focus groups for each role at each site. 6-12 participants, 12 focus groups, average 1.5h long Used Herbert Clark's theory of communication 6 investigators reviewed all transcripts and identified concepts, which were aggregated into categories following substantial review and discussion by the authors across multiple iterations and rounds of analysis Focused on one theme from another study - communication and coordination Organized results according to general levels of joint action, the common heuristics to establish common ground, and the effort to establish meaning through mental models	Templated information diminishes the exchange of information and creates information overload Increased cognitive work to get to the needed and relevant information Skepticism about copy and paste information creating inaccuracies and creating work to validate and cross check information The vast amount of information in shared workspace creates feeling of needing to understand it all Nurses' notes not read by others because of effort required to sort through large, bulky templates outweighed information gained, nurses knowing this caused them to resort to verbal exchanges Information in EHR not chronological and required cognitive work to create a chronology of events and connect them meaningfully CPD failed to help form big picture view of the patient and key intentions of the provider System doesn't consolidate vast amounts of	Strengths: Multisite and various perspectives 12 focus groups All 6 investigators participated in data analysis and synthesis Reached saturation, resolved discrepancies in interpretations Limitations: Single EHR that had been in use for a long time Focus groups subject to conformity pressures Single source of data Did not fully describe process around data analysis	Templated information reduces exchange of information Increased cognitive work Skeptical about information from copy and paste Information overload, pressure to understand it all Nurses notes not read, increased verbal exchange Lack of chronology, have to create that on own Lack of overview and intention EHR does not support planning, coordinating, establishing common ground	Focus groups

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
				information in a way that is useful, requires sorting, sifting, managing Findings suggest there is an unmet need to support the higher-level components of the joint action hierarchy, such as planning, coordinating, and establishing common ground			

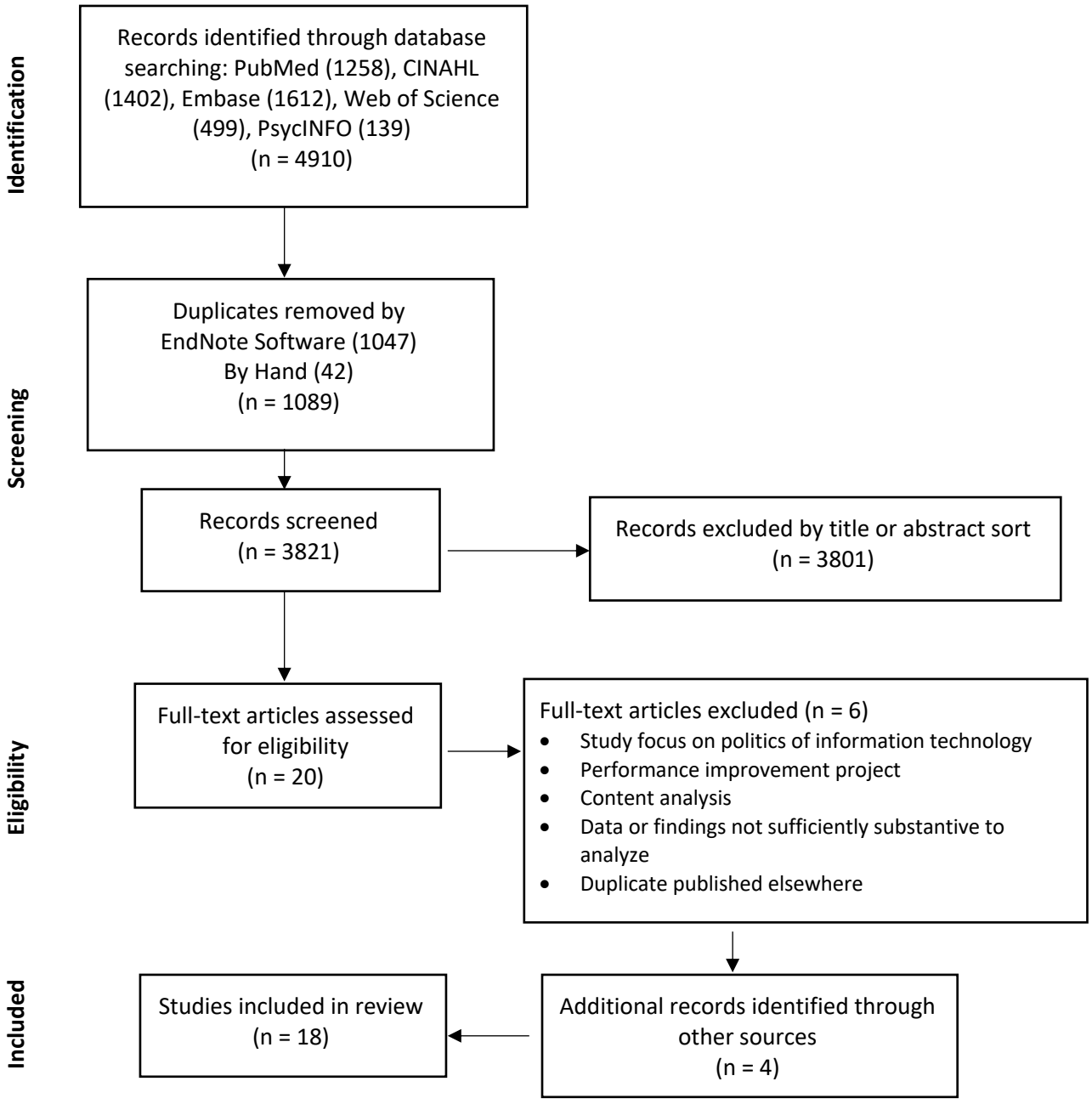
Note. BSN = bachelor of science in nursing; CPOE = computerized physician order entry; ED = emergency department; EHR = electronic health record; ICU = intensive care unit; IRB = institutional review board; IT = information technology; MS = medical surgical; NICU = neonatal intensive care unit; OH = Ohio; PI = principal investigator; RA = research assistant; UT = Utah; VA = veteran's administration; VS = vital signs; WA = Washington

Table 2.4 *Supplementary File: Summary of Studies Included in Review*

Citation	Setting, Sample	Purpose	Design and Methods	Findings	Strengths, Limitations	Themes	Instruments
Zadvinskis, I. M., Chipps, E., & Yen, P. Y. (2014). Exploring nurses' confirmed expectations regarding health IT: a phenomenological study. *International Journal of Medical Informatics, 83*(2), 89-98	U.S. MS unit in an academic medical center Purposive sample of nurses who had experience with the EHR Inclusion: worked 2 years with the organization N=10 nurses, 80% BSN, age range 29-50, 3-20 years' experience	Gain an understanding regarding EHR implementation process and strategies and evaluate the impact on patient care from the staff nurses' perspective Explored nurses' perceptions regarding health information technology and identify performance, teamwork, patient safety and quality of care expectations	Qualitative, phenomenology Individual semi-structured interviews lasting 20-60 minutes Field notes and interviews transcribed Interviewer was a PhD student. Participants familiar with her and her experience because she had been doing observations collecting data for concurrent time-motion study 3 researchers participated in data analysis, read transcripts independently to identify units of meaning. Generated common themes by synthesizing the meaning units from iterative discussion	EHR documentation for patient physical assessment was not set up to correspond to the nurses' mental model, resulting in frustration and inefficiency Information was all there but was fragmented Sequence of information difficult to find and use	Strengths: 3 researchers participated in data analysis Read transcripts independently, then synthesized meaning units iteratively as a team Discussed positionality of person doing data collection Limitations: Single unit, small sample but said they sought and reached saturation Most (70%) of data collection was on day shift so may not reflect unique issues on night shift. 80% of nurses were BSN prepared and slightly younger (29-50) than national average Only one source of data	EHR documentation did not match nurses' mental model Frustration and inefficiency Information there but fragmented Sequence of information difficult to find and use	Interviews

Note. BSN = bachelor of science in nursing; CPOE = computerized physician order entry; ED = emergency department; EHR = electronic health record; ICU = intensive care unit; IRB = institutional review board; IT = information technology; MS = medical surgical; NICU = neonatal intensive care unit; OH = Ohio; PI = principal investigator; RA = research assistant; UT = Utah; VA = veteran's administration; VS = vital signs; WA = Washington

Figure 2.1 *Study Selection Process*



Chapter 3

Managing the Tension Between Caring and Charting: Labor and Delivery Nurses' Experiences of the Electronic Health Record

Abstract

Background and objective: There has been rapid and widespread implementation of electronic health records (EHRs) in the past decade. Recent estimates report that they are used in 95% of hospitals and 86% of physician offices in the United States. A growing body of literature suggests that EHR use creates cognitive challenges for clinicians. Labor and delivery nurses' cognitive support needs may differ from other nurses' needs, yet no studies have investigated this topic in labor and delivery settings. This study sought to explore labor nurses' perceptions of the impact of the EHR on their cognitive work and to identify related safety implications.

Methods and setting: This was a constructivist grounded theory study with a purposive sample of 21 nurses from two community hospital labor and delivery units.

Results: Nurses' processes around configuring care when using the EHR were shaped by how they integrated the EHR into their practice. This took place in a dynamic, high-acuity, specialty clinical environment while using EHRs that were not designed for pregnant women. Factors at the individual, group, and situational level facilitated or constrained integration. Nurses viewed the quality of their relationships with patients and families as an integral part of caring for laboring women and felt that interaction with the EHR sometimes threatened this dimension of their work. Fetal monitoring information documented in a house-wide EHR was difficult to easily review and understand. Participants in this study found it challenging to integrate the EHR into their care of laboring women and reported loss of overview of the patient's clinical status, loss of individual and team situation awareness, and inadequate access to key information sources such as prenatal records.

Conclusions: These findings represent important safety considerations that align with issues reported in other studies of clinicians' experiences with EHR use. More research is needed to

inform EHR designs that support nurse-patient interaction and to better understand how to integrate electronic fetal monitoring data in ways that facilitate the ability to efficiently retrieve and interpret it when documented in the EHR.

Background and Significance

There has been rapid and widespread implementation of electronic health records (EHRs) in the past decade. Recent estimates indicate that EHRs are used in 95% of hospitals and 86% of physician offices in the United States (The Office of the National Coordinator for Health Information Technology [ONC], 2019). Their use was expected to drive significant safety gains related to improved communication, complete information access, reduced medication-related errors, and support for clinical decision-making (Aspden, Corrigan, Wolcott, & Erickson, 2004; Page, 2004). Many of the anticipated benefits of EHRs have not been realized and unexpected problems have been associated with their use (Schiff et al., 2015; Sittig, Wright, Ash, & Singh, 2016; Wisner, Lyndon, & Chesla, 2019). A growing focus on the cognitive burden generated by EHR use has fueled national efforts to bring together stakeholders representing policy, clinician, and vendor perspectives in order to better understand this burden and improve the usability of EHRs (Office of the National Coordinator for Health IT [ONC], 2018; Tcheng et al., 2017).

Although nursing is the largest profession in the U.S. healthcare workforce (U.S. Department of Health and Human Services, 2017), most of the public discourse and research about the EHR's impact on clinicians' cognitive work has focused on physicians (Schulte & Fry, 2019; ONC, 2018; Tcheng et al., 2017). While few studies have sought to explore clearly defined aspects of nurses' cognitive work, numerous studies have reported incidental findings suggesting that the EHR has introduced cognitive challenges that may have important patient safety implications. A recent integrative review on this topic reported on five themes: 1) loss of overview of the patient's status; 2) the cognitive work of navigating the EHR; 3) limited support from EHR-generated cognitive tools; 4) difficulty establishing a shared understanding of the

patient's status; and 5) loss of information and professional domain knowledge (Wisner, Lyndon, & Chesla, 2019).

Labor and delivery nurses face unique challenges when using the EHR since they also use and document care in a fetal monitoring system that may not interface with the organization-level EHR, adding to the complexity of information retrieval and synthesis and thus introducing distinct cognitive challenges. Limited EHR research has been conducted in perinatal settings, and no studies have examined the EHR's impact on labor and delivery nurses' cognitive work. This represents a troubling gap in the literature since most labor and delivery nurses work in community hospitals using nurse-managed models of care (Simpson, 2005). The ability to accurately perceive and anticipate the patient's clinical situation (Benner, Hooper-Kyriakidis, & Stannard, 1999; Endsley, 1995) when working in this type of setting has important implications since these nurses often work relatively autonomously, making critical decisions regarding when to consult a provider or engage the team to escalate care when faced with a clinical concern.

The purpose of this study was to explore labor and delivery nurses' perceptions of how interaction with and use of the EHR affects their cognitive work, with the goal of understanding patient safety implications.

Methods

Design and Data Collection Methods

This grounded theory study sought to explore how labor and delivery nurses' interaction with the EHR impacts their cognitive work, with a focus on elucidating any safety implications. The goal of the analysis was to present a theoretical explanation of how the EHR shapes important aspects of nurses' cognitive work (Charmaz, 2014).

Data were collected between July 2018 and June 2019 with a purposive sample of registered nurses working in the labor and delivery units in two community hospitals in the Western United States. Individual, semi-structured, open-ended interviews were used to explore nurses' perceptions of the EHR and how it affected their cognitive work. An interview guide developed from sensitizing concepts (Blumer, 1969) and themes from the literature was used to structure interviews, and this was adapted as the analysis evolved. Two types of participant observations (shadow and unit-based) were included to further explore themes from interview data, to experience first-hand how nurses used and interacted with the EHR, and to uncover participants' tacit or taken-for-granted understandings. Shadow observations involved following an individual nurse for 1-3 hours during their shift. Unit observations were conducted near the nurses' station and involved observing clinician interactions with each other and with the EHR. Detailed field notes were recorded during observations and reviewed immediately afterward to ensure accuracy. Interviews were recorded and professionally transcribed. One of the researchers verified the accuracy of all transcripts by checking them against the recordings (Kvale, 1996).

Participants were selected based on their clinical experience and likelihood of being able to contribute to an understanding of the study aim (Strauss, 1987). Nurses who agreed to an interview were invited to participate in a shadow observation scheduled at a later date. Nurses were eligible to participate in the study if they had at least 6 months experience working on the designated unit and worked at least 16 hours per week. While sampling was not predetermined based on demographic characteristics, nurses were sought who might contribute different perspectives based on age, experience, and other factors. Recommendations were also solicited from nurses during their interview.

Analysis. Transcripts from interviews and field notes were managed using ATLAS.ti qualitative analysis software version 8.3.1 (Scientific Software Development GmbH, 2019). Data were collected and analyzed simultaneously using constant comparison (Glaser & Strauss, 1967; Charmaz, 2014), open, focused, and theoretical coding (Charmaz, 2014), and memoing and diagramming (Charmaz, 2014; Clarke, 2005). Memoing was used to examine the data at the code, incident, and dimension level, and explore the relationships of various dimensions within and across participants. Dimensions in dimensional analysis (Schatzman, 1991) are analogous to categories in traditional grounded theory (Glaser & Strauss, 1967). Memoing was also used to identify gaps in the data, direct theoretical sampling, develop an understanding of the core processes, and to fully develop and saturate the most salient dimensions (Charmaz, 2014; Schatzman, 1991; Kools et al., 1996). Situational mapping was used to explore the research phenomenon in the broader local, organizational, regulatory, and political context (See **Table 3.1**) (Clarke, 2005).

Dimensional analysis, a grounded theory method developed by Schatzman (1991) and expanded on by Kools and colleagues (1996), was used to interrogate and situate other relevant dimensions around the central perspective that best explained labor nurses' experiences of EHR use. These were organized according to how they best fit as part of the context, conditions, actions/processes, and consequences (see **Table 3.2**) (Kools et al., 1996; Schatzman, 1991). Context represents the situation where the phenomenon is embedded; conditions facilitate, impede, or influence the participants' central actions and processes; processes are the actions fueled and shaped by the conditions; and the consequences are the outcomes resulting from these processes (Kools et al., 1996; Schatzman, 1991).

Methodological rigor. Rigor was maintained through sustained immersion in the field and appropriate sampling of participants (Tracy, 2010). Credibility of the data was ensured through the use of thick description, multivocality, and member reflection (Tracy, 2010; Whittemore, Chase, & Mandle, 2001). Reflexivity, or attention to researcher positionality, was maintained via the use of memos, journaling, and peer dialogue to ensure self-reflection at all stages of the research process and confirm that analytic interpretations were grounded in the data (Whittemore et al, 2001). Real-time checks of assumptions during interviews and observations were used to clarify understandings and ensure that researcher interpretations were representative of participants' thoughts and meanings (Ericsson & Simon, 1998; Varpio et al., 2015). Peer feedback was sought when reviewing transcripts of interviews and observations in order to evaluate and continually refine interview and observation techniques (Charmaz, 2014).

Measures to protect participants. Human subjects review and approval was obtained from the University of California, San Francisco (UCSF) Institutional Review Board (IRB) and from each research site's IRB. Informed consent was obtained from nurses participating in individual interviews. The interview and observation protocol was approved at site A and interviews alone were approved at site B. The consent included a query asking if the participant was available to participate in a follow-up interview (both sites) and in a shadow observation (at site A). For observations, verbal consent was obtained from staff, patients, and families whom were present while the nurse was being observed. Participants were reminded of their right to withdraw from the study at any time. No personal identifiers or protected health information was recorded during observations. Participants were given a $25 gift card for completing the interview.

Results

Twenty one nurses participated in the study, 11 from site A and 10 from site B. All nurses participated in an interview lasting 45-90 minutes, 7 nurses from site A participated in a shadow observation lasting between 75-135 minutes, and 2 unit observations were conducted. All participants were women, with a median age of 49 (range 36-64). Self-reported ethnicity was 80% Caucasian, 10% Hispanic/Latino, and 10% Black and Asian. Nurses had worked in labor and delivery for a median of 20 years (range 5-36) and most had not worked in another specialty. The major difference in the sample across the 2 sites was that most nurses had a bachelor's degree or higher at site B, whereas just over half of nurses at site A had an associate degree and the remainder had a bachelor's or higher degree. Additional participant demographic characteristics are summarized in **Table 3.3**.

Settings and EHRs Used

Both sites were community hospitals with 250-300 licensed beds and an annual birth volume between 1600 and 4000. Sites were similar in that they both used a labor-delivery-recovery model of care with a separate postpartum unit, had a level III neonatal intensive care unit, and had an obstetric emergency department within their triage unit. Nurses were represented by unions at both sites and worked a combination of 8- and 12-hour shifts at site A and 8-hour shifts at site B. The care scenarios described by participants reflected a high degree of adherence to the Association of Women's Health, Obstetric, and Neonatal Nurses ([AWHONN], 2010) recommended staffing ratios.

Nurses worked in two EHR systems at site A; most of the admission, labor, delivery, and recovery documentation for vaginal and cesarean birth occurred in the fetal monitoring system. Nurses were discouraged from running a paper electronic fetal monitoring tracing at this site, and

all documentation on the tracing was done virtually. Physician orders and documentation, laboratory and diagnostic tests, medication management, and intake and output were managed in a hospital-wide system, so nurses documented, retrieved and reviewed information in both systems. A third system was used by anesthesiologists in the operating room and post-anesthesia care unit, although nurses had no access to this system. There were pervasive issues with interoperability and transfer of information between the 3 systems in use at this site. The EHR had been in place for approximately 7 years.

At site B, nurses managed information and documented in the hospital-wide EHR system, and a separate system was used for fetal monitoring. Nurses ran a paper fetal monitor tracing at this site and were also able to view an electronically archived tracing, although they did no documentation in this system. An interface between the two systems facilitated the transfer of vital signs, an estimated fetal heart rate baseline, and calculation of Montevideo units (a measure of uterine contraction intensity) from the fetal monitoring system to the main EHR, which had been in place for approximately 3 years.

Findings

The dimension with the most explanatory power to depict how labor nurses experienced the EHR was *configuring care when using the EHR,* which was shaped by how the nurse *integrated the EHR* into their practice. This took place in a dynamic, high-acuity, specialty clinical environment while using EHRs that were not designed for pregnant women. Various factors at the individual, group, and situational level facilitated or constrained nurses' ability to integrate the EHR into their care. Nurses saw the quality of their relationship with patients and their families as an integral part of caring for laboring women and felt that interaction with the

EHR sometimes threatened this dimension of their work. When nurses were unable to integrate the EHR into care it resulted in numerous consequences that have important safety implications.

Context: The labor and delivery environment. The labor and delivery environment was dynamic and rapidly changing, where fluctuations in patient acuity and time constraints shaped how nurses used the EHR as they balanced the competing demands of patient care and documentation. Nurses often cared for patients across a continuum of care and sequential events. The EHR systems used were not tailored for perinatal settings, which introduced issues with the accuracy of information and made summary and other features such as alerts less useful. Nurses were eager to contribute to improving the EHR, but change processes were often complicated and sluggish and nurses felt frustrated by not having an efficient and clear path to process their concerns.

Rapidly changing, high-acuity clinical environment. Nurses readily explained how they accounted for this uncertainty and fluctuating acuity by describing two routines they used to compile multiple information sources when assuming care of a patient. The first pathway was considered ideal, when there was ample time to review information from the previous nurse's report, the prenatal record, the EHR, and the patient, and to synthesize these data to establish an understanding of the patient's clinical status. When faced with time constraints, such as when assuming care of a patient needing immediate attention due to an imminent birth, nurses used information from report (if taking over care from someone else) or from the patient (if a direct admission), and quickly assessed the situation through interaction with the patient and family.

> *In labor and delivery, events can happen very quickly. It's not like you can just presume that you're going to just be able to sit down and slowly and methodically go through your electronic medical record and just go along through a steady pace with your patient care through the day. There are a lot of opportunities for unexpected events or simultaneous unexpected events to occur. There's always an opportunity for chaos to happen. (P26 Site B)*

Provided I have time, I'll review their prenatal record, and their chart. I'll look at notes that the doctor has written, any ultrasound or lab results that might be pertinent to the case. If I come into a room and the patient's pushing then I don't have time to do any of that stuff. So I just have to rely on the report that I've been given and the current situation, my observations and interactions, and go from there. (P5 Site A)

Managing sequential events. Labor nurses often cared for a patient along a continuum of care—triage, labor, birth, and recovery, and managed these events in both normal and urgent situations. Each of these phases of care required managing separate orders, as well as documentation templates and screens, which added to the volume and complexity of their documentation.

Maybe you pushed for a couple hours with your patient, and you weren't able to keep up with your charting during that time, depending on how much labor support she needed. You need to catch up on all that push charting that you missed, and then chart the delivery, and all the stuff on the baby, plus you're also into your recovery. Then they need help. Maybe they're bleeding, so you're watching that closely. Or it's their first baby and they want more breastfeeding support, and at that point, you're just not leaving the room. (P9 Site A)

Each one of these things are a specialty in and of themselves. We do triage, labor, delivery, C-sections, recovery, newborn babies. These all have their own order sets, their own policies and procedures, all with different standards of care. (P23 Site B)

The structure of the EHR. Nurses in this study used EHRs that were not structured for pregnant women. They often navigated screens and templates that did not match their patient or their workflow, and at times worked in screens that were missing important assessments or aspects of care. This added to documentation complexity and affected the accuracy of information in the EHR when the documentation structure complicated or impeded nurses' ability to capture the care scenario. In addition, this made intended cognitive support features such as summary or handoff screens less useful for supporting overview of the patient and often

rendered alert and alarm features ineffective. In many cases, these features introduced a nuisance to nurses as they worked around information that was immaterial to their patient.

> *Things that you should be talking to OB patients about for fall risk aren't [in the EHR] because fall risk is set up for 80-year-old people on the med surg unit who are confused. You can fall for different reasons [in OB]. Things I think we should be talking to our patients about would be if they had significant blood loss, [instructing them to] sit up and get acclimated before walking because of orthostatic hypotension. And discussing what they should do if they think they might fall, like find a chair quickly, or just bring yourself to the ground before falling to the ground. But again, the EHR's not customized for pregnant women. (P23 Site B)*

Change processes to improve the EHR. Nurses were frustrated by complicated or slow change processes and by not having a clear pathway to advocate for EHR system improvements. This seemed to be exacerbated by being in a specialty unit, since the main information technology support in the organization was focused on general care. Nurses wanted to be part of change processes that could result in EHRs that were responsive to their practice needs, but felt that processes either did not exist or were too slow. The sense that the systems being used were not actively or easily revised in response to feedback was apparent at both sites, although for different reasons, and there were more pervasive issues at site A. Nurses at site B felt encouraged to contribute their ideas for EHR design improvements, and there were nurses on the unit with specialized knowledge about the system who were available for support. However, progress was sometimes hindered by the overall complexity of the EHR. Moving a change request through the system was not only dependent on internal stakeholders and actions, but also required that end-users, such as physicians, were aware of and implemented the change.

> *[This Hospital] is really, really proactive about trying to fix things to make it work for nurses. (P30 Site B)*

> *I'm on the [Council]. We have a nurse who is really enthusiastic, and she keeps trying to fix things. We wanted to be able to get a heating pad on an order set. She's like, "Okay, I'm going to put in a work order for that." She gets the order added to the order set, but*

then it doesn't go through. She later learned that if the doctor didn't set themselves up for receiving changes [to the order sets], it doesn't go through. [The physicians] don't know this, she didn't know this. It took her about six months to realize what the problem was. (P29 Site B)

At site A, nurses were frustrated by not being part of system design or involved in improvements. There was neither a clear process for contributing their feedback and advocating for system improvements nor a designated information technology support person for perinatal services.

This comes up fairly often that we're saying, when decisions are made [on the unit], or even in the hospital in general, "They didn't even think about us at all." (P3 Site A)

We don't really have a go-to person or a process to make suggestions. [It would be great] to have bedside nurses that were part of this and say, "Okay, this is what we want it to look like to give us a better picture." It does breed apathy. Satisfaction for me would be somebody behind the scenes saying, "Hey. Lets' make this the best product we can…concise, easy to navigate". For ease of use, but more importantly to paint an accurate picture and gather information that's really pertinent to this patient. (P11 Site A)

Conditions: Factors that shaped how nurses integrated the EHR. The degree to which nurses were able to integrate the EHR into their practice emerged as the dimension that most influenced how nurses configured their care when using the EHR. When integration was successful, nurses configured care in a way that resulted in feeling connected to the patient, having a sense of overview, and feeling confident about their documentation and care. When unable to integrate the EHR successfully, nurses experienced the EHR as a distraction and stressor that created conflict for them as they managed the competing demands of electronic documentation and patient care.

I like the idea that they can almost see what you're charting. When I'm on the computer, I try to engage the patient at the same time, so that they feel like they're a part of the charting process, part of putting information in the computer, what their care is, and [they see me enter] their answer to the question I'm asking them.(P17 Site B)

I apologize to every single patient for it because I feel like I'm facing the computer more than I'm facing them and that's not how my nursing career started. I feel like it's always nagging you from behind somehow when the patient needs your full attention, and there's something in the back of your mind, "I better do that computer." So that's kind of how I feel about the whole computer thing, whereas the [paper] flow sheet was just really easy. (P1 Site A)

The quotes above represent the spectrum of nurses' experiences, which varied within and across participants and sites. Factors at the individual-, group, and situation-level shaped how nurses integrated the EHR.

Individual factors included the nurse's prior experience as a labor nurse and with the EHR, including their perspectives about technology and about being "hands-on" and connecting with the patient. The degree to which nurses perceived the relative importance of documentation in the context of other priorities sometimes influenced how they configured care.

I think that probably the biggest thing that stands out to me is the time that we're sitting on a computer instead of face-to-face [with the patient]. I'm not sure if we miss care, but maybe care could be better if we weren't worried about the required documentation, or whether we clicked all the boxes, or finished it all. We're so preoccupied, that maybe we just glance at vital signs, or quickly assume, "Oh, the patient looks okay." But we're not really fully assessing. (P24 Site B)

I think maybe other nurses are more structured in how they enter data, but in my mind, the process of triaging is what's most important and the documentation, if I have to do it later, then I do it later. I try to get in and just see the patient and get as much done as I can and then if I need to go back and document, that's okay. (P3 Site A)

Group-level factors included unit/organizational culture, the organization of EHR-related work, and perceived rewards or consequences for being proficient with documentation versus focusing on the patient. Nurses often bore the responsibility of putting information together for others and making information accessible for those who did not have access to the perinatal EHR system. At site A, anesthesiologists used a different electronic system and thus were dependent

on nurses to provide them with patient history information needed to administer an epidural. In this case, the nurse's focus on completing the documentation is a form of advocacy for the patient—paving the way for them to get adequate pain management if needed.

> *What happens is the unit clerk says, "I can't make the chart until you do the admission." The nurse is saying, "I need the chart. I need stickers. I need that chart to do the epidural." They don't feel like they can call the anesthesiologist, because the anesthesiologist will say, "Where's the chart?" And there's no chart. The unit clerk will sometimes call. "Where's my papers? How come she's not admitted? I see that her admission is not done." This all reinforces the need to get the admission done. (P3 Site A)*

Nurses were concerned with their competency with the EHR. They perceived that adeptness in documentation contributed to being considered a better nurse since efficient documenters were good at throughput. There were perceived management pressures to be efficient with documentation and to not incur overtime. Integrating the EHR was influenced by the extent to which the nurse was affected by these social or organizational pressures.

> *I think if you're really good at the computer, you become very efficient at getting a patient through the system. So you're lauded for efficiency and throughput. And the sooner you can get your patient out to [postpartum], the better nurse you are. The charge nurses know who those nurses are ... and those are the "good nurses" because they can get the patient in and out. (P23 Site B)*

> *Those nurses who are great hands-on in labor support, they're always there overtime to finish their charting. And I see, especially on day shift, our manager walk by, and they're like, "Oh, you're still here." If they have a lot of overtime on their time cards, the manager will sort of mention that to them. (P24 Site B)*

Nurses defined being a "good charter" versus being "hands-on" as skills that existed along a continuum, and in most cases were perceived as skills that conflicted with each other.

> *There are four groups. The first group are amazing hands-on. They're at the bedside, in the shower, they provide continuous labor support. They take great care of their patients, but their skills at the computer are minimal. The second group can click all the boxes and get all their documentation done, but they're not so great hands-on and they aren't at the bedside. Then there's a group in the middle—I think that's where most of us fall— we can*

get by with the computer and are good at the bedside. The fourth group are awesome hands-on and great at the computer, but that's a very, very, small, small group. (P24 Site B)

Environmental or situational factors, such as the functioning of equipment, affected the ease of integrating the EHR. Nurses were sensitive to how patients might respond to seeing them troubleshooting equipment and worked to shield the patient from additional stress. Participants were also concerned that the complexity of EHR-related work, especially when it did not go as planned, interfered with their attention to other care that they saw as important.

You're dependent on the functioning of the equipment. If I go to scan [to give a medication], and the scanner is not working, I'll have to find another and there's a lot of troubleshooting that is stressful and frustrating and makes me feel self-conscious in front of a patient when things aren't flowing smoothly. [The patient is dealing] with enough that we don't need to be fumbling with our equipment and things like that too. That adds a lot of stress for me. You have to scan the computer, scan the patient, scan the medication, enter it in the computer, answer questions like pain level and then also blood pressure or heart rate depending on the type of medication you're giving. After all of that, then, "Okay, I can give the medication." There's a lot of steps in doing what seems like a simple task. Something's [being lost] in that time…..whether it's face-to-face time with the patient, or hands-on time at the bedside. (P25 Site A)

Processes: Configuring care—managing the tension between caring and charting. All but one nurse in this study made the transition from paper to the EHR as a labor and delivery nurse, and most participants articulated how EHR use differed from their prior experience using paper charting. While nurses generally did not express a desire to go back to paper, the work of configuring care and documentation was more difficult for them when using the EHR. Challenges were related to the work of navigating the EHR and managing and synthesizing information, interpreting and contextualizing information, and to the EHR's impact on nurses' interaction and connection with the patient. The nurse's overall experience with the EHR was shaped by their ability to integrate the EHR into their care.

Navigating, managing, and synthesizing information in the EHR. The EHR facilitated collecting and aggregating volumes of information; however, nurses found the layout and organization of this information difficult to navigate. This created additional cognitive work for them as they searched and compiled information, problem-solved issues working in screens and templates, and synthesized information to make it clinically meaningful to them.

While the EHR design simulated the paper chart layout with features such as tabs and sections, and these features were likely intended to support the ability to view and associate information, nurses could not readily connect and synthesize data across sections in the record. They were concerned that the data fragmentation and challenges with information synthesis led to inadequate cognitive support and missing information.

> *A [paper chart] had a glossary and tabs…and an EHR can have a glossary and tabs too, but for some reason it's different. I feel so much more disconnected clicking and opening tabs and going back [and forth], I don't feel comfortable flowing from one tab to the next…It just seems like with the paper chart things were closer together. Who knows what kind of information or support you're missing in that respect…we've all just adapted to this hunt and peck mentality. (P25 Site A)*

Key sources of information, such as prenatal records and nurses' narrative notes, were entered into the EHR via several different pathways, making information retrieval more difficult as nurses searched for them in multiple places.

> *[With the paper chart] you had tabs, and there'd be consents in one place, the prenatal in one place. There wasn't a lot of information or a lot of paper, but it was everything that you needed for your patient. You would think that you could just go and find information [in the] EHR. But now, the prenatals, it depends on the office—some prenatals merge over to our system, but others have to be physically scanned in. So we don't just have a Prenatal Tab on the computer to find the prenatal. We have to go through different tabs and search, and it might not be the most up to date one. It just feels like a lot of searching for information. Whereas before, it was just all in the chart. (P27 Site B)*

Interpreting and contextualizing information. Nurses felt that information presented in templates, and the structure and organization of information in the EHR did not facilitate their ability to see the evolution of assessments over time, or changes in the patient's condition. This impeded their ability to build an understanding of how their patient was doing and to follow the temporal progression of their and others' care. The diminished use of narratives and reliance on checklists and standardized text obstructed nurses' holistic, clinical sense of the patient. In certain cases, the structured information options did not account for normal changes, like those expected in skin color or vital signs in a normal newborn during transition. While the EHR collected a lot of information, it also scattered and fragmented it, tasking the nurse with the work of putting it back together to generate a comprehensive understanding of the patient's clinical status.

> *I'm thinking of the newborn assessment. A newborn will change a lot in its transition. They might be acrocyanotic the first six hours of life, they have good skin color for the next 12 hours of life. Then they're starting to develop newborn rash, jaundice, different things like that and you can't see a pattern. You can only chart what you're seeing right now. You can't see like, "Is this baby more jaundice than it was earlier?" Unless you dig and look back at other people's assessments of things or if they've written a note, whatever 10 or 20 hours of age, infant identified as being jaundice or something like that. I think can be too generalized if you're just relying on the multiple choice and [fewer narrative notes] ... You just don't see that reflection or comparison very well. (P25 Site A)*

On the one hand, templates provided a structure to work within that prompted nurses to remember what to document. However, this structure was limiting when documentation options were missing, or was cumbersome when the layout of information did not match the nurse's workflow.

> *I don't think we captured as much when we were writing stuff because your narrative was kind of coming the top off your head, but now we're queued all the time. I like [that] it gives you a framework to work inside so it gives you some choices - which can be bad*

because sometimes what you need to [document] isn't even there. And [we have things like] Fentanyl [the most common pain med we use] is at the bottom of the drop-down list and not at the top. (P4 Site A)

There was variation at the two sites in how well the EHR supported fetal monitoring interpretation, particularly the ability to access a summary view of all assessment elements of the fetal heart rate tracing in order to appreciate the evolution of the tracing over time. At site A, nurses viewed the documentation system that was associated with the electronic fetal monitoring favorably, and felt it helped them to see the progress and trends in the patient's condition.

You can see the progress of labor from when she walked in the door to right now. The [electronic fetal monitoring (EFM) system] seems more fluid than [Main EHR]. Maybe it has something to do with the strip and the continuous documenting on the strip because there's just continuity in that. [EFM system] is a better system than the [Main EHR] for identifying or reviewing because even when you go to the flowsheet, if you look at what her vaginal exams have been over the last eight hours, it pops right up. You know what kind of progress she's made. (P25 Site A)

At site B, they did not use a software that was associated with the fetal monitoring system and instead documented electronic fetal monitoring assessments in the hospital-wide EHR. Nurses at this site reported difficulty interpreting the fetal heart rate pattern evolution when viewing data documented by others in this system. It required the nurse to toggle in and out of documentation fields and reconstruct a prior nurse's assessment, which they often did not do since assessing for themselves was easier. They could not readily view other nurses' clinical interpretations of electronic fetal monitoring assessments.

Sometimes the doctor will ask, "How long has the baby been this way?" and they want it now. But you're like, "One second," and so I will click on the variability tab and it will show me [past entries] but then I can't relate that variability to what the heart rate was because I then have to go to the heart rate [tab]. It's not like you see a full flow sheet [with the information together]. And so I often just review the actual strip and tell them what my interpretation of what it was like seven hours prior. But I can't just look really quickly. It all takes a lot of time. (P28 Site B)

Connecting and interacting with the patient and family were primary ways that nurses obtained information about the patient, yet nurses sometimes found attention to the EHR challenged their ability to do so. Nurses often framed the tension between charting and caring for the patient as a dilemma that they faced, or a choice they had to make when configuring their priorities.

> *If you haven't figured out how to make peace with using the EHR and don't have your own system of navigating it, then it's tough to do two things at once and to have your brain be focused on two things at once. You can't. So I feel like there's a high chance of either missing something with your charting, which can introduce a liability, especially in an emergency, or you're not going to give the best care that you could give, because you're trying to chart instead of taking care of the patient. I don't think it makes you a bad nurse if your brain goes to the charting. I just think that that's just how your brain works. I don't think that the EHR helps [us integrate these two things]. (P26 Site B)*

In addition to serving as an information source, connecting and interacting with the patient were seen as integral to caring for laboring women. Nurses were sensitive to their patients' emotional state and worked to protect them from situations that they felt might threaten their experience or feelings of safety. Nurses deliberately attended to creating connection and trust with their patients, and they viewed their interaction with the EHR as a potential threat to this dimension of their work.

> *I think in healthcare, if we want to have good patient experiences and things like that, we need to have a human connection. We need to show that we're not rushed when we're with them and that we're making eye contact and seeing them and having a conversation with them. I think that's where we need to be sensitive with the EHR. I know that they've made efforts to make it better, but the computers are still quite cumbersome. It would be nice if they were more discreet. (P25 Site A)*

> *I feel like [the EHR] invades the space incredibly. It's this whole thing that's happening, and I see it more and more. You have to spend so much time looking at the screen that the interaction with the patient is definitely diminished. (P29 Site B)*

They need to trust you. This is a pretty rough time in their life. They need to trust that you're taking good care of them, and it takes a lot of energy to earn that trust, and then for you to be able to take care of them and their baby, and for their husband, their wife. There's so many different people that you are spending so much energy on just to get them to trust you to let you take good care of them that sometimes there's not enough of that energy left for charting. That's how I feel. And I would rather put forth my mental energy towards making sure that the patient feels well cared for and taking good care of her and her baby. I would rather spend my energy doing that than to stress about the charting. (P24 Site B)

Nurses adapted how they configured care, and their processes around information gathering and management in response to the patient's acuity and needs. All nurses reported that in fast-paced, high-acuity situations, they did not use the EHR at all, either as an information source or for documentation, because interacting with the computer impeded their ability to focus on the patient. The exception was when there was an additional nurse available to focus solely on documentation. In these high-acuity situations, nurses relied heavily on their direct assessment of the patient and on interaction with the patient and/or family. They used various paper sources to track what was happening and went back later to chart in the EHR.

If her health situation is changing rapidly, I'm probably not going to use the EHR. At that point, you have to assess the patient on your own, and try to get information from the patient, or sometimes from the family. "Has she been doing this before? Has this happened? Have you noticed that her face is swollen?" If you're not getting report from another nurse, say the patient just walked in and she's getting rushed to a C-section, then you just have to go in there and do it, jump in and do it on your own. Then later you go back into the record. (P1 Site A)

Sometimes I find it hard to keep up, especially during a recovery, do the charting as I'm doing it, 'cause there's just so much to do with Mom and baby that I find it easier just to do it, get my hands on. 'Cause if you do the charting at the same time, you're kind of getting pulled away from actually helping families with what they need. (P9 Site A)

If it's a high-acuity situation, I don't use the computer. I chart on my strip for emergent things like position changes, O2, medications, vacuum applied, etc. So, my strip is still my go-to thing, and then everything is charted retro. (P30 Site B)

Consequences. When nurses were able to integrate the EHR and felt comfortable navigating in it, this supported their ability to obtain and maintain overview and their ability to understand and synthesize information.

> *There are a lot of functions that help you see trends. You can see her labor curve on there. You can see vital sign trends with a click of a button. Those are kind of nice to look at, if you take the time to [view those things] versus scrolling back and just looking at flow sheet information where you can actually see it kind of in the bigger picture. Which you know in nursing sometimes you have to be careful that we get very detail focused about again, we're charting on that 30 minute strip. We're not paying attention to what this kid has been telling you for the last two shifts about his condition. I do like the fact that it compiles that data and can help give you the bigger overall picture to make some of your decisions. (P30 Site B)*

When nurses were unable to fully integrate the computer into care, this reconfigured how they managed the competing demands of patient care, processed and managed information, and documentation, and this had numerous consequences. When nurses' attention was directed toward the computer and resulted in a diminished focus on the patient, this led to a loss of situation awareness and to potentially unsafe conditions for the patient.

> *I heard the patient scream and I came in to see what was going on, to see if they need more help. The nurse was at the computer, staring at the computer and doing the admit. The baby, the 32 week baby was coming out. I was like, "Hmm, the priority." Of course, the patient needed to be admitted, but really what we needed was to take care of the patient, and call NICU. From the desk, I could hear the patient was probably going to deliver. I don't feel like I've been in that situation, I hope, but I've witnessed it where I was like, "Wow. What if the nurse didn't feel so much pressure to enter that data?" If she was more mentally and just physically present with the patient....To me, what I thought was she's missing what's right ... I mean literally in front of her, screaming for help and she feels like that's not the priority. (P3 Site A)*

In addition to loss of immediate situation awareness as captured in the quote above, there was a loss of overview on a broader level as well. When nurses were unable to organize and synthesize information in a way that enabled them to see information chronologically, or in a

relevant clinical context, this resulted in a loss of overview of the patient's status and an understanding of the trajectory of their clinical status. While the promise of the EHR was to make accurate, updated, and complete information about patients available at the point of care, there was concern about lack of access to important information sources like prenatal records. Nurses worried that the team had a diminished sense of patients' history and risk factors.

> *The way the EHR is set up now is different than before, and I have concerns that we may miss things that we used to see before, like trends in the prenatal, like notes that used to be easy to see on that prenatal versus having to search for them week-by-week. "What week was it that they talked about her compliance for her diabetes?" You have to do a lot more searching, and there's a sense that we lost that ability to really have a good lens on where this woman was before she came in the hospital, because of the way the records are fragmented. And often it doesn't seem like most nurses, and even on-call physicians don't fully read that prenatal before they care for that patient. It's just the way that it's set up doesn't ... the time that you need to get grounded in your work, and get going with what you need to do, the tasks that you need to do, doesn't necessarily allow you to fully [review the record]. (P23 Site B)*

Most nurses felt that something was compromised when managing the tension between being thorough with documentation and connecting with and providing good care for the patient.

> *I don't think you can [thoroughly document and give great care]. Some nurses are lauded on the fact that they can do it, but I would challenge [the assumption that these nurses are actually doing both of these things well]. I've observed nurses in the operating room not looking at the instruments when they're being counted…looking at the computer and just clicking off the boxes. I was trained that when you're counting, you're confirming. You're looking at the field, you're seeing those instruments, you're seeing those sponges, and you're confirming, "Yeah, there's five needles, there's 10 sponges, there's all these instruments." You're confirming that with your own eyes. But I see people's eyes on the computer. How can your eyes be two places at once? (P23 Site B)*

Discussion

This is the first study to explore labor and delivery nurses' perceptions of how EHR use affects their cognitive work. While a few participants were fluid in using the EHR in an integrated fashion, most participants found interaction with the EHR challenging and struggled

to successfully integrate it into their work. Navigating the organization and layout of information in the EHR was difficult and impeded nurses' ability to formulate and maintain overview of the patient's status as they searched for and compiled information, problem-solved issues they encountered when working in screens and templates, and synthesized data across multiple information sources. Nurses were concerned that the effort required to locate certain information sources, such as prenatal records, resulted in a loss of both individual and team awareness of the patient's history and risk factors. Nurses reported documenting and using narrative notes less frequently since the transition to electronic documentation. The shift from narratives to information in templates resulted in diminished support for nurses' ability to contextualize and see information in ways that helped them understand the unfolding of a clinical situation or to appreciate the clinical implications of various data.

Other studies have reported challenges with contextualizing and synthesizing information from the EHR and loss of overview of the patient's status at the individual and team level (Chao, 2016; Embi et al., 2013; Keenan et al., 2013; Schenk et al., 2016; Staggers, Clark, Blaz, & Kapsandoy, 2011; 2012; Stevenson & Nilsson, 2011; Varpio et al., 2015; Vikkelsø, 2005; Weir et al., 2011). Clinicians have also reported that the structure of information in templates often fails to support their ability to interpret associated clinical implications and the evolution of a patient's condition, making it more difficult to interpret and use information documented by others (Chao, 2016; Embi et al., 2013; Staggers et al., 2012; Varpio et al., 2015; Weir et al., 2011).

Nurses deliberately developed connection and trust with patients and their families and viewed this dimension of their work as integral to quality care in labor and delivery. Interaction with patients was also seen as a primary information source and nurses sometimes felt that

attending to the EHR and its associated technology threatened this dimension of their work. The quality of connection and interpersonal relationships during labor and birth are also viewed by women as integral to their overall birth experience and their perceptions of safety (Lyndon, Malana, Hedli, Sherman, & Lee, 2018).

In high-acuity or emergency situations, participants in this study reported they did not use the EHR at all, but instead relied on paper to track care, which resulted in duplicate documentation—first on paper, and later in the EHR. This is similar to Embi and colleagues (2013) who reported that nurses found it difficult to align documentation in the EHR with the fast-paced and mobile nature of their work. Abandoning the EHR in high-acuity situations was reported by all participants in this study, even those who felt proficient with the EHR, which has important implications for how organizations support nurses' use of paper tools. EHR design should be adaptive to real-life clinical situations and allow for the integration of paper sources that nurses find helpful to them and provide needed cognitive support.

One of the central promises of the EHR was to make information readily available and accessible (HealthIT.gov, 2018); however, nurses at both sites reported pervasive problems with accessing the patient's prenatal record and history. Much of this was due to system interface and interoperability issues. The ease and degree of access to a patient's medical and obstetric history have been linked to maternal and neonatal outcomes, and clinicians working in EHRs where information is automatically transferred from ambulatory or office settings to discrete fields in inpatient settings report higher use of such information (Meyerhoefer et al., 2017).

This is the first study to report on nurses' perceptions of the efficacy of the EHR-electronic fetal monitoring interface in supporting their ability to interpret electronic fetal monitoring information, particularly the ability to quickly evaluate pattern evolution over time.

Nurses used different systems at the two study sites, and those who worked in software designed for the electronic fetal monitoring system perceived it more favorably and reported that it supported this aspect of their work. Nurses working in a house-wide EHR that had not been customized for labor and delivery reported difficulty understanding the trajectory of maternal and fetal status when reviewing information documented by others in the EHR. This caused them to go back and review the previous tracing and come to their own conclusions about the patient's prior status, which required additional time and effort.

Limitations

Nurses were from two community hospitals in the Western United States and worked in EHRs with varying degrees of sophistication and system integration. The findings may not apply to other settings where fully integrated EHRs are in place. While we sought community hospital settings because this is where the majority of labor nurses work (Simpson, 2005), nurses working in other types of settings may have different experiences with the EHR. The age range of nurses in this study was 36 to 64, with a median age of 49. This is younger than the estimated median age of employed nurses in the United States (Smiley et al., 2018). However, the age range did not represent the 20% of nurses that are <35 years old; hence the findings may not apply to younger nurses. Nurses were represented by unions and worked in settings in which there was a high level of adherence to AWHONN staffing guidelines; therefore nurses working in settings with heavier workloads may have different experiences with EHRs.

A strength of this study was its immersive, qualitative methodology which allowed for an exploration of the sociotechnical aspects of EHR use. Experts from cognitive science suggest that understanding the challenges that clinicians face when executing complex cognitive work require observations, interviews and artifacts analysis (Lintern & Motavalli, 2018). The findings

from this study are consistent with challenges reported elsewhere in the EHR literature, therefore they may be transferrable to other labor and delivery settings.

Clinical and Research Implications

Participants in this study found it challenging to integrate the EHR into their care of laboring women and reported loss of overview of the patient's clinical status, loss of individual and team situation awareness, and inadequate access to key information sources, such as prenatal records. These represent important safety considerations and align with issues reported in other studies of clinicians' experiences with EHR use (Sittig et al., 2016; Wisner et al, 2019). Nurses prioritized their ability to interact and form a relationship with their patients and families but found that EHR use sometimes impeded their ability to do this.

Many of the issues identified in these data could be improved by actively engaging end-users and streamlining change processes. Continuous end-user input and engagement are recommended as key strategies for improving the safety and usability of EHRs (Office of the National Coordinator for Health IT [ONC], 2016; Tcheng et al., 2017). The ease with which nurses integrated the EHR into their practice was shaped by individual, organizational and environmental factors. At the individual level, a nurse's fluency with the EHR and prior experiences affected integration, as did environmental factors such as having to troubleshoot technology and equipment that were not working. These issues could be improved by providing increased access to information technology support that is readily accessible in real time and by more proactive management of devices and equipment by engineering staff. This might include ongoing EHR training or the availability of EHR champions on the unit, and regular equipment and technology checks. The findings from this study also suggest that nurses should be supported

in using the paper electronic fetal monitoring tracing if they find this helpful for recording and interpreting information.

Using human factors and sociotechnical systems frameworks, future research could focus on understanding what types of EHR design features and data presentation best support how labor nurses retrieve, organize, synthesize, and communicate information; how to integrate narrative notes and evaluate handoff and summary tools specifically for labor and delivery; and how to effectively support clinical grasp and situation awareness. In addition, more research is needed to inform the design of EHR-electronic fetal monitoring integration and interfaces that support the nurse's ability to interpret fetal status and tolerance to labor and respond in a timely manner and on understanding what types of EHR design features support or hinder nurse-patient interaction.

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Table 3.1 *Ordered Situational Map: The EHR and Nurses' Work*

Individual Human Elements/Actors • Nurses • Physicians • Patients • The fetus • Families • Hospital Admin/Mgrs • IT Department/Personnel	**Discursive Constructions of Individual and/or Collective Human Actors** • Individual Clinician Competence/Skill Level • Team Functioning • Communication Processes • The Social System • Task Saturation • Cognitive Load/Cognitive Function • Safety Culture	**Temporal Elements** • Volume/Acuity on the Unit • The Patient's Stability/Acuity • Staffing Adequacy • Temporal documentation issues
Collective Human Elements/Actors • Regulatory Agencies (CMS, AHRQ, ONC) • Professional Organizations (AWHONN, ACOG, AMIA, etc.) • HIT/EHR Vendors • FHM System Vendors • Quality/Safety Organizations (CMQCC, TJC, BetaHC) • CNA	**Implicated/Silent Actors/Actants** • The Baby • The patient • The family/support persons • Collective - health care consumers	**Spatial Elements** • Workspace Design • Access to Supplies/Equipment • Placement of the computer containing the EHR in the room and between the nurse/clinician and patient • How documentation cubbies/spaces are structured on the unit -Do physicians have their backs to RNs? -Are RNs and other clinicians visible and accessible to patients?
Nonhuman Elements/Actants • The EHR/HIT • The EFM System • Technological Devices (SurgiCount, IV/Epid Pumps, EKG and other monitors) • Medication Administration Devices/Technology • Billing Requirements in EHR	**Discursive Constructions of Nonhuman Actants** • Workflow Processes • System Complexity • Controversy around the Affordable Care Act (ACA) • Organizational pressures to achieve meaningful use	**Technological Elements** • Interaction b/w Technology and the Individual • Interaction b/w Technology and the Social System • Technology Infrastructure • Technology Interface Issues
Political/Economic Elements • American Recovery and Investment Act of 2009 ○ HITECH Act • Budgetary Constraints • Productivity and Efficiency Pressures • HCAHPS Reimbursement Pressures	**Related Discourses (Historical, Narrative, and/or Visual)** • Nurses Caring Discourse • The Art of Nursing Discourse • High-Touch L&D Nursing Care Discourse • Ageism and Technology Discourse	**Moral and Cultural Elements** • Age of the Clinician • Clinician-Patient Interaction/Connection • Language Barriers b/w Clinician/Patient • Clinician Satisfaction/Well-Being
Key Events in the Situation • US Government Incentives/Support for HIT/EHR Use	**Major Issues/Debates (Usually Contested)** • Hardwiring the System for Safety Discourse (more is better) • Technology Enhances Safety Discourse	**Sociocultural/Symbolic Elements**

Table 3.2 *Dimensional Matrix of the Central Perspective Configuring Care—Managing the Tension Between Caring and Charting*

Context	Conditions	Processes	Consequences
The labor and delivery environment	**The factors that shaped how nurses integrated the EHR**	**Configuring care—managing the tension between caring and charting**	• Successfully obtaining and maintaining overview, synthesis of information • Confidence in care and documentation, connected to patient • Reconfiguration of care, diminished focus on the patient and loss of overview and situation awareness • Diminished understanding of clinical trajectory, chronology of care • Loss of team overview • Conflict between documentation and being with the patient

• Rapidly changing, high-acuity clinical environment
• Managing sequential events
• EHR structure designed for general care[1]
• Ineffective change processes for improving the EHR
	• Individual factors
	  ○ Prior experience as a labor nurse[2]
	• Group-level factors
	  ○ Unit or organizational culture[3]
	  ○ Pressure to perform: The EHR as a new competency
	  ○ Continuum of being a good charter vs being hands on
	• Environmental and situational factors
	  ○ Interaction with equipment
		• Navigating, managing, synthesizing information from/in the EHR
		• Interpreting and contextualizing information
		  ○ Information templates
		  ○ Fetal monitoring interpretation
		• Connecting and interacting with the patient and family
		  ○ Protecting the RN-patient relationship: Creating connection and trust
		  ○ Responding to patient and family acuity[4]	

[1]The structure of EHRs are designed for general care, so medication times, various assessments like fall risk, pressure injury, etc. are not structured for L&D patients. In addition, available IT or informatics support is focused on general care

[2]Personal perspectives about technology, interacting with patients, and being hands-on. Also includes the extent that the social pressure to perform or be a "good charter" affects them

[3]How the overall culture and system shape thinking and prioritization; social or organizational rewards or consequences for issues with documentation (just culture, punitive) and rewards or consequences for being/not being a great charter and being hands-on

[4]This includes not using the EHR in high-acuity situations, going back to paper, duplicate documentation

Table 3.3 *Participant Demographic Characteristics*

Number of Participants	**21**
Median Age (Range)	49 (36-64)
Median Years in Setting (Range)	20 (5-38)
Highest Degree	
• Associates/Diploma	7 (33%)
• Bachelors	10 (48%)
• Masters	4 (19%)
Shift	
• Days	10 (48%)
• PMs	7 (33%)
• Nights	4 (19%)
Role	
• Charge RN/Shift Supervisor/Coordinator	5 (24%)
• Clinical Nurse	16 (76%)
Ethnicity	
• White	17 (80%)
• Asian	1 (5%)
• Black	1 (5%)
• Hispanic/Latino	2 (10%)

Chapter 4

Labor and Delivery Nurses' Use of Cognitive Support Features in the Electronic Health Record

Abstract

Background and objective: There is a growing appreciation of the cognitive burden that poorly designed or implemented clinical decision support generates for clinicians. Most large-scale efforts to improve the electronic health record and clinical decision support have focused on physician- or provider-specific issues. These efforts call for a more robust application of user-centered design principles and a better understanding of clinicians' cognitive work. Nurses' perspectives are generally missing from these initiatives. Labor and delivery nurses encounter novel challenges when using electronic health records since they also interact with a fetal monitoring system, and their cognitive support needs require the integration of specialty knowledge and expertise under dynamic conditions. The purpose of this study was to explore labor and delivery nurses' use of cognitive support features in the electronic health record.

Methods and setting: This was a grounded theory study using dimensional and situational analysis. Data were interviews and observations with 21 labor nurses at two community hospitals in the Western U.S.

Results: Nurses in this study worked in electronic health records not designed for pregnant women, which rendered most of the intended cognitive support features ineffective. The exception was the electronic medication administration record and bar code medication verification, which nurses perceived as helpful to catch and avoid medication errors. Other features such as summary or handoff tools, risk assessment screens, alerts and reminders, and disease-specific templates were either not used as intended or were seen as a distraction that created extra work. In some cases, there were missed opportunities for cognitive support, such as with structured templates for high-risk assessments, and with the overall structure of required documentation screens.

Conclusions: Available cognitive support features lacked the specialty-specific support needed to care for laboring women and instead required nurses to track information in other ways that added to their cognitive burden and work routines. Nurses and patients were not benefitting from the intended decision support and patient safety protections offered by appropriate risk assessment screens or critical alerts. There should be policies and guidelines in place that address the selection and implementation of appropriately designed and configured electronic health records in perinatal settings that support rather than hinder nurses' cognitive work.

Introduction

Many of the targeted safety, quality, and efficiency goals related to electronic health record (EHR) use presume that clinicians will successfully adopt and benefit from features and functions in the EHR designed to provide cognitive support. These include electronic clinical decision support (CDS)—tools embedded in the EHR designed to deliver person-specific, clinically relevant information during point-of-care decision-making (Office of the National Coordinator for Health IT [ONC], 2018a; Tcheng et al., 2017). While CDS applications have also been designed for patients and other stakeholders, those intended for clinicians include alerts, reminders, prompts and assists; clinical guidelines, condition-specific order sets and protocols; focused reports and summaries; documentation templates; pertinent reference information; and diagnostic support (Healthcare Information and Management Systems Society [HIMSS], 2019; ONC, 2018a; Tcheng et al., 2017). There is a growing appreciation of the cognitive burden that poorly designed or implemented CDS generates for clinicians. Users have found them disruptive and inconsistent, and report that they are typically integrated into workflows in ways that fail to support clinical decision-making and care processes (ONC, 2018b; Tcheng et al., 2017).

Most large-scale efforts to improve the usability of EHRs and improve CDS have focused on physician- or provider-specific issues, such as with computerized provider order entry, or those encountered in office or clinic settings (ONC, 2018b; Tcheng et al., 2017). These efforts call for a more robust application of user-centered design principles and a better understanding of clinicians' cognitive work. Nurses' perspectives are generally missing from these initiatives; which is troubling since they comprise the largest profession in the U.S. healthcare workforce (U.S. Department of Health and Human Services, 2017), and their work requires constant

interaction with the EHR and its associated technologies. While the literature on CDS and nurses' work is limited, a recent review about the EHRs impact on nurses' cognitive work reported that nurses generally did not use EHR-generated patient summary and handoff tools and instead relied on tailored paper forms or on verbal exchanges (Wisner, Lyndon, & Chesla, 2019), suggesting that these features within the EHR have failed to provide the contextualized and synthesized information support that nurses need. Forging forward with improvement efforts without an understanding of the unique challenges encountered by nurses will likely fail to improve usability for them and may introduce additional unintended consequences.

Labor nurses encounter novel challenges when using EHRs due to the fact that they interact with a fetal monitoring system in addition to the EHR, and their cognitive support needs require the integration of specialty knowledge and expertise under dynamic conditions (Wisner, 2019). Moreover, most women give birth in community hospitals, where the majority of moment-to-moment labor care may be managed and administered by nurses under the remote supervision of a physician or midwife (Simpson, 2005). The need for cognitive support in the intrapartum environment may be very different from other nursing environments, yet we could find no studies in intrapartum settings that have focused on understanding labor nurses' perspectives about EHR use or CDS. This paper stems from a larger study exploring labor and delivery nurses' perceptions of how EHR use affects their cognitive work, the main findings of which are presented elsewhere (Wisner, 2019). The analysis presented here focused specifically on labor and delivery nurses' use of cognitive support features in the EHR.

Design and Methods

Data for this grounded theory study were collected between July 2018 and June 2019 from a purposive sample of registered nurses working in the labor and delivery units in two

community hospitals in the Western United States. The lead author conducted individual semi-structured, open-ended interviews and participant observations. Interviews were recorded, professionally transcribed, and checked for accuracy (Kvale, 1996). Shadow observations of individual nurses during their workday as well as unit observations were used to explore how nurses used and interacted with the EHR and to probe themes from interview data. Field notes taken during observations were transcribed immediately afterward. Participants were selected based on their clinical experience and likelihood of being able to contribute to an understanding of the study aim. Nurses were eligible for participation in the study if they had a minimum of 6 months experience working on their unit and worked at least 16 hours per week.

Analysis

Data collection and analysis were simultaneous and ongoing using constant comparison (Glaser & Strauss, 1967; Charmaz, 2014), open, focused, and theoretical coding (Charmaz, 2014), and memoing and diagramming (Charmaz, 2014; Clark, 2005). Dimensional analysis, an alternative grounded theory method developed by Schatzman (1991) and later expanded on by Kools and colleagues (1996), was used to explore the data. In dimensional analysis, dimensions are analogous to categories in traditional grounded theory. Once a critical mass of dimensions and their associated properties were developed, the dimension with the most salient explanatory power was explored in the context of other related dimensions for its context, conditions, processes and consequences (Kools et al., 1996; Schatzman, 1991) (see **Table 4.1**). Data were managed and analyzed using ATLAS.ti software version 8.3.1 (Scientific Software Development, GmbH, 2019).

Memoing was used throughout the analysis to probe the data and relationships within and across dimensions and participants, as well as to guide theoretical sampling (Charmaz, 2014;

Glaser & Strauss, 1967). We deliberately selected and tracked quotations and associated themes in the data that represented differences in participants' experiences as well as the range of variation across and within participants and settings. Memoing and peer dialogue ensured reflexivity through all stages of the study (Whittemore et al., 2001). The first author interrogated analytic assumptions in real-time with participants during interviews and observations as well as during weekly analysis meetings with peers (Charmaz, 2014).

Measures to Protect Participants

The University of California, San Francisco (UCSF) Institutional Review Board (IRB) and each site's IRB granted human subjects approval. Nurses gave signed informed consent for individual interviews. Interviews and observations were approved at site A and interviews alone were approved at site B. Consents were structured accordingly and included a query regarding shadow observations at site A. Verbal consent was obtained from staff, patients, and families whom were present during observations of individual nurses. No personal identifiers or protected health information was recorded during observations. Participants received a $25 gift card for their interview.

Results

Twenty-one nurses participated in the study. All nurses participated in a private interview lasting between 45-90 minutes, 7 nurses participated in a shadow observation lasting 75-135 minutes, and 2 unit observations were conducted. Participant demographic characteristics are summarized in **Table 4.2**.

Settings and EHRs Used

Both sites were community hospitals with 250-300 beds and 1600-4000 annual births. Settings used a labor-delivery-recovery model, had level III neonatal intensive care units, and

obstetric emergency departments as part of their triage units. Nurses worked 8- and 12-hour shifts at site A and 8-hour shifts at site B. The care scenarios described by participants reflected a high degree of adherence to the Association of Women's Health, Obstetric, and Neonatal Nurses ([AWHONN], 2010) staffing ratios. Two EHRs were used at site A and one Main EHR was used at site B. See **Table 4.3** for additional information about the EHRs used.

Context: Using a One-Size-Fits-All EHR in a Specialty Unit

The specialty clinical environment in labor and delivery presented novel challenges around EHR use. Labor nurses managed CDS features in EHRs that were not customized for the perinatal patient and that therefore did not account for the laboratory values and risk factors unique to pregnancy. Additionally, nurses interacted with a separate fetal monitoring system.

The structure of the EHR. Nurses worked in at least one EHR that was not designed for the peripartum period. This created numerous issues as they worked with preconfigured screens, templates, and risk assessments that did not reflect care scenarios in labor and delivery. They worked around alerts and risk assessments, did not use or partially used summary reports, struggled with documenting labor and delivery-specific scenarios surrounding the administration of intravenous fluids and certain medications, and viewed forcing functions in the EHR as opaque and obstructive. This added complexity to nurses' documentation and the flow of their work and affected information accuracy.

> *I think that there's a lot of idealistic [ideas with the EHR], and we're expected to do so many things to follow requirements, etc. But, it's [not configured] to support us to really follow what we're supposed [to do] ... because no nurse wants to do the wrong thing. Whether it's charting, whether it's care. But, we don't have the tools to do it, in my opinion. (P11 Site A)*

Pregnancy physiology. Caring for women during labor and birth requires extensive specialty knowledge and tailored cognitive support. Pregnancy involves changes in all

physiologic systems. The alterations in cardiovascular, respiratory, renal, hepatic, and immune function affect the interpretation of vital signs and laboratory values, and introduce unique vulnerabilities surrounding medications, hemorrhage, infection, and falls (Blackburn, 2014). A woman's stability during labor and birth can change quickly, requiring rapid interpretation of clinical status and timely intervention. Thus, the CDS features that come in preconfigured systems designed for general care are more likely to fire or present at inappropriate times and are not designed to detect actual threats in the perinatal patient. Unfortunately, EHR customization can be quite costly and may not be feasible for smaller organizations (ONC, 2018b). Local alterations by information technology staff may unintentionally disarm built-in safety features (ONC, 2018b) and produce an EHR-in-use that differs considerably from its intended design (Harrison et al., 2007). These problems may be enhanced in labor and delivery due to the physiologic differences and needs of laboring women.

Conditions: Reallocating CDS Customization to the Nurse

Level of CDS customization. CDS features must be designed to respond to clinically relevant information in order to be pertinent and effective. Nurses at both sites in this study did extra work related to managing information that was not customized for pregnant women. This included responding to alerts, documenting in screens that did not match their patient, and correcting information in templates or orders entered by others. This nullified the purpose of CDS, which is to provide cognitive support features that are person-specific and clinically relevant (ONC, 2018a).

> *You have to uncheck things that don't apply to your patient. We've been having a lot of issues with doctors just not unchecking things. They just click [the boxes that are required] and hit file. So, we have patients who are preeclamptic but they have methergine ordered. Or a patient with severe asthma and Hemabate is still checked. Well, if it's ordered the nurse can technically give it [so we need to catch those*

inappropriate medications]. It could have severe implications to the patient if you carry out that order. (P8 Site A)

Use of the paper electronic fetal monitoring (EFM) tracing. While the paper EFM tracing does not fit into a typical definition of CDS, access to and use of the paper fetal monitor tracing emerged as an important cognitive support tool for nurses in this study. This was particularly true in high acuity or emergency situations, since documentation on the paper tracing provided a structure that supported the nurse's ability to track events and interventions in relation to maternal and fetal status. The fetal monitor tracing is a visual representation of the fetal heart rate and maternal uterine contraction pattern that reflects fetal status and tolerance to labor and is used to evaluate fetal status over time. As reported elsewhere, all nurses, even those who felt comfortable with the EHR, reported that in emergency or high-acuity situations they did not use the EHR to retrieve or document information (Wisner, 2019). In these cases, nurses tracked information on paper and went back into the EHR later to document. In this context, the use of a continuous paper EFM tracing supported nurses' ability to more readily track information within a relevant framework and maintain a focus on the patient.

Nurses' use of the paper EFM tracing was different at the two study sites. At site A, nurses were discouraged from running a paper tracing and were instead directed to assess and document in the fetal monitoring system electronically. In high-acuity situations, these nurses reported using other forms of paper and using the "mark" button on the EFM. The mark button documents a symbol on the electronic (or paper) tracing but has no associated data unless the user documents it. Nurses routinely ran a continuous paper EFM tracing at site B, and relied heavily on the ability to make written notes on the paper tracing during high-acuity events.

As far as the charting, I liked the paper [EFM tracing, which is no longer available]. It was easier to jot down notes real quick in emergency situations. In lieu of just pushing the mark button and then going back and trying to remember okay why did I push it

here? Why here? Why did I push it there? When you have a baby that's not doing well, you need to take action and focus on the patient, [not on trying to remember what each mark button was for]. (P5 Site A)

I love my paper strip [EFM tracing], if that went away, I don't know what I would do. I definitely chart from the strip, and put it all onto the strip. Especially, let's say if I'm the second nurse in a delivery, and I'm just going in, they're doing a vacuum or whatever. I chart everything on the strip to keep a record of it. (P27 Site B)

Processes: Labor Nurses Working With and Around Ineffective CDS

Organizing features. There were organizing features in the systems used at both sites that nurses found both helpful and distracting. At site A, the main hospital EHR system had a worklist display with clocks to remind nurses to document certain assessments and tasks at specified intervals and alerted them when medications were due. Site B had a summary tab that provided an overview of all required documentation and displayed green or red check marks to help nurses track what had been completed.

At site A the organizing features were in the main hospital system, but were tied to documentation that was required in the EHR system used only in labor and delivery. Because the two systems were not fully interoperable, work done in the system used in labor and delivery was not registered as completed by the main hospital system. This meant that the nurse had to go in and clear those clocks as an extra step in order for this feature to be helpful to them.

She does a lot of other documentation dealing with the clocks - clicks about 20 clocks in total. After selecting a group of them, she selects not documented and a text box appears at the bottom of the drop-down. She types a free text entry "in [EFM System]." I note that this should be a drop-down option if it is something nurses have to do often. (Observation notes - P19 Site A)

At site B, nurses could view an organizing screen with an overview of the status of all of the required documentation. This was helpful to many nurses; however, it appeared that the

feature had not been updated as new documentation screens were added. Therefore it was missing important specialty-specific documentation expectations.

> *There's this box that you can click, and it's an interesting box because it says "Required documents," right. I click it, I do it. And, it's great, because it does remind you like, "Oh shoot, I didn't update the care plan." Or, "I didn't do their fall risk thing," or whatever. …. But [certain things aren't there], like hemorrhage risk isn't in there, nor is sepsis risk. (P23 Site B)*

Electronic summary or handoff tools. One of the promises of CDS was to provide appropriate, single-patient data summaries that clarify and consolidate a patient's information in order to focus the clinician's attention on pertinent issues (HIMSS, 2019; Tcheng et al., 2017). An ideal clinical summary makes key patient- and situation-specific information needed for optimal decision-making available and is tailored to the clinician's role and routines (HIMSS, 2019).

Electronic summary tools were not used to full potential at either site, making them less useful for supporting nurses' ability to assemble a comprehensive understanding of the patient's clinical status. This was largely due to their design or how they were implemented and/or enculturated at the study sites. Most nurses used some form of a paper summary during their shift and during handoff, indicating that paper tools provided better support for tracking and synthesizing information.

At site A, there was an electronic summary screen available in the EFM System offered by the vendor, but the information technology team had not developed and implemented it. Labor nurses at this site used a paper report sheet that they filled out at the beginning of the shift and updated throughout. The postpartum nurses and nurses in other units worked only in the main EHR and used a summary report screen generated from that system. This meant labor nurses compiled information from multiple sources to create an overview of the patient's status

and to communicate pertinent information during handoff, especially when transferring a patient from labor to postpartum or to another area within the hospital.

> *My understanding is that [EFM System] can generate a report sheet. So, we have [Main EHR], [EFM System], and we're doing this handwritten report. It's frustrating that we're not using the capabilities of [EFM System], and instead we're trying to recall everything. We're not using what [tools] we do have that would benefit nurses. So, we're mixing reports... two different computer systems plus paper. P11 Site A*

At site B, a labor and delivery handoff summary screen had been developed but had not been adopted by most nurses. This was influenced by nurses' comfort level and/or established routine with summarizing information on paper, as well as by their perception of the summary function not having been fully tailored to their patient population, which made it less useful to them. In addition, users had to know how to configure their EHR user profile to activate this tool, which seemed to require a specialist's understanding of the EHR.

> *For handoff, I'll pull up L&D Handoff and look over the patient history, labs, vitals, most recent vaginal exam, fetal heart rate information, and then get bedside handoff from the nurse. I think before the L&D handoff summary report had been built, it was a little bit more challenging because the reports didn't really follow along with what we needed. Now we have that, but a lot of nurses aren't using it yet. I'm still configuring their screens [when I notice they aren't using it], and then they find it helpful. So I think people just need to get a little bit more used to that. I think [not using it] is probably one of the challenges for people to see the big picture. P20 Site B*

Alert features in the EHR. Event-driven alerts and notifications are among the types of CDS designed to inform or remind a clinician to attend to a particular issue, such as an abnormal lab result, new orders, or expected interventions (HIMSS, 2019). Guidelines recommend that computerized provider order entry should generate an electronic notification (via an alert or messaging) to the person responsible for implementing the order. In addition, there should be a process in place to detect and track orders that are not acknowledged within a specified timeframe and escalate these to a supervisor (ONC, 2016a).

The structure of the EHRs used by nurses in this study rendered many of the intended alert features ineffective and contributed to alert fatigue. Nurses managed electronic alerts for standard adult laboratory values instead of for pregnant women, which distracted them and sometimes caused them to miss or delay noticing and responding to abnormal lab values.

> *You get pop-ups of critical values, which aren't critical, and then when you have a critical value, it doesn't prompt you to act on it. And that's because the EHR isn't customized for pregnant women's labs. We're treating this pregnant woman with this EMR, like she's a 60-year-old male, and she should have those lab values. P23 Site B*

At site A, this was further complicated by nurses working in multiple systems: since they used the EFM system throughout labor and recovery and interacted less frequently with the main EHR, they missed notifications about new physician orders or other relevant alerts since these did not transfer to the EFM system.

> *When you're a med-surg or mother-baby nurse, you're only using [Main EHR]. In labor, we're using [EFM System] and [Main EHR]. We used to work so [closely] with our doctors and they'd say, "Hey, I've put an order in for Pit..." Now, we have younger doctors who are savvy with the computer, so they may put an order in and not see or talk to you, and they assume you'll see it. But, if you don't go back into [Main EHR] for a couple of hours, because there's no reason to, then you may not see that order for a while [and you may miss an important order]. P11 Site A*

Laboratory staff at both sites called the labor unit to inform them about critical lab values; however, these staff were not trained to accurately interpret normal pregnancy lab values. Hence nurses were alerted first by the EHR, and again by a phone call, and oftentimes neither alert process was relevant to their patient.

> *They pop up when it's not a critical lab value for a pregnant woman. We get those and they call us, "I have to tell the nurse this." So, the nurse is interrupted, comes out of the room for them to tell you something that we all know is irrelevant. P29 Site B*

Standardized automated orders triggered on admission and suited for the medical-surgical or general patient population were applied without consideration of their implications in

pregnancy. Reconfiguring these orders and associated alerts to account for pregnancy was not always straightforward for nurses. This added to the work required to manage them, and oftentimes they were left unresolved, which added to alert fatigue.

> *Sometimes you'll get stuff over and over. The best practice orders and stuff that will pop up because it's been flagged in the computer. Like a flu shot, which is in the labor order set. Once the order is activated, the computer prompts you to give it right away. You're not going to give it to her in the middle of labor—that's not for labor, it's for [postpartum]. So, there are best practice things that pop up and get fed into the MAR [medication administration record] incorrectly and then you have to go back and restructure all of that, [which isn't easy or clear, knowing how to do it]. Typically what happens is you keep pressing the ignore button, then you pass that information onto the next nurse. So, it becomes this annoyance that's constantly popping up and nobody seems to know how to get rid of it. P29 Site B*

Automated functions in the medication administration record (MAR). We could find no clear CDS literature about the intended support offered by automated calculations of intravenous fluid intake extracted from the MAR. The rationale may be derived from the microergonomics principle of function allocation, where tasks are assigned to humans or machines based on which is thought to have the potential to execute it more effectively (Challenger, Clegg, & Shepherd, 2013). Automated calculations in the EHR would fall into the machines-are-better-at versus humans-are-better-at assumption (Challenger et al., 2013), presuming that the EHR is better equipped to calculate intake and clinicians would derive some type of cognitive support from automating this function.

While there was some variation at the two sites, in general these automated features did not support nurses' work as intended because they did not account for scenarios in labor and delivery. The ability to edit information to accurately reflect the situation was either limited or challenging because it required multiple steps. Nurses had to manage these steps in the middle of other work or remember to address them later. For example, physician orders in labor and

delivery often provide some discretion for labor nurses to administer IV fluid boluses for intrauterine resuscitation or in preparation for regional analgesia; however, the MAR did not accurately reflect such orders. This made it challenging for nurses to correctly document these boluses as well as to accurately record the rates and volumes infused for oxytocin and IV antibiotics. Nurses were often unable to override or correct automated functions, which added to the number of things they needed to remember to track and respond to in the EHR, and resulted in unresolved errors in the patient's medical record.

> *It calculates an intake and a volume infused - volume infused and volume in the bag. If I put down what I actually have, the system analyzes it, and it changes the rate, to compensate for what I have in the bag. [You can't override it]. If there was a way to override it I could have done it. (P6 Site A)*

> *[The MAR] will keep up with [calculating the IV intake], but I've only known one other nurse that oriented me at [another hospital] that really keeps up with [inputting] her boluses and her antibiotics and all of that [in the MAR], so that that number stays similar to the pump. If you're going do an IV bolus, and then give antibiotics [and don't adjust rates in the MAR] you can't use the computer because it's off, so I go off of the pump. It doesn't hurt to use [the MAR], like at the end of the day, it's better than guesstimating. And it depends on the situation too. If I'm really, really behind and I'm doing my I&Os and the other person didn't clear [the pump] I will just use the computer…when it's such a mess I will. I would say 30% of the time I use the computer to kind of just end my shift, clean everything up and hand off. (P28 Site B)*

The automation of IV fluid calculations was particularly problematic with oxytocin administration for induction/augmentation of labor, since the rate of this medication is often increased at regular, frequent intervals. When managing oxytocin at site A it was challenging to keep up with documentation of rate changes in both the EFM system and the main EHR because of the lack of system integration. When nurses tried to rectify IV fluid intake from the oxytocin infusion at the end of the day they had to manipulate the system to correct it.

> *When we do our I&Os and you give the credit exactly the way it is at the end of shift or the end of the patient stay, it's not going to add exactly what the patient got. Because you*

scan it, it goes in, then when you scan a second bag it's going to automatically calculate that for you. But when we're running an IV bag with Pitocin that we're titrating, we're titrating the drip on the pump and in [EFM System] but not on the MAR in [Main EHR]. (P2 Site A)

Electronic medication administration record and bar code medication administration. Nurses viewed the electronic medication administration record and related bar code medication administration/verification processes and features as safety enhancements and readily described how the extra steps involved in scanning a medication had caught errors before reaching the patient.

So I'd much rather have the device do it for us and there have been situations where, in a crisis, people have brought meds into the room to give for say uterine tachysystole to stop contraction and have brought the wrong medication, and one that absolutely would do the opposite and make things so much worse and even jeopardize the fetus. But because we stopped and used the scanner, it showed an error message, we realized, "Hey, this is the wrong medication. We don't want to give this, we want to give that." (P20 Site B)

I love [the bar code medication verification]. We make a lot less errors, it has saved me from making errors, which is awesome. (P4 Site A)

Other features in the electronic medication administration record enhanced safety and offered cognitive support. For example, before administering medications where blood pressure assessment was important, the nurse was prompted to assess and document vital signs and flagged them if abnormal.

With the MAR it would trigger [a blood pressure] that's high or a low, like with Methergine or some of the blood pressure medications, it will ask me what the vitals are and it'll also highlight if they're too low or too high. That's a benefit. (P4 Site A)

Risk assessments. The SAFER guides recommend that clinical staff are regularly involved in the evaluation of protocols and other CDS features in the EHR to assess them for relevance in their particular clinical setting (ONC, 2016c). Nurses in this study used risk assessments, such as for falls, that were tailored to the medical surgical population. This created

extra work that nurses perceived as irrelevant and illogical and distracted them from caring for their patients.

> *There's a sit-and-stand test. Can they sit there? Can they shake your hand, and this and that? It takes up time for us to click all those things when 99% of our patients walk in the door. So of course they can stand, shake your hand, stand on one leg. And there's a lot of areas [in the EHR] we don't even go that are left blank, and you feel like you should chart something there, but probably you don't need to. It's not really appropriate for our patient population. (P24 Site B)*

> *Well, I think the fall risk evaluation is not completely accurate in that we have healthy, capable people who are ambulating and walking well without a disability, but they may have a procedure that limits their ability for the short-term. If a patient is bedfast for 12 hours, but has the ability to move themselves well in the bed, that's a different evaluation than someone who is bedfast and paraplegic and not able to move. I don't know how well [the fall risk] interprets [our patients]. There's a list of four questions, like bedfast, chairfast, something else, and ambulation. I pick bedfast because I'm not getting her out of bed for 12 hours and it's a safety issue, but it's not because she's required to stay in bed because of a physical disability. I see those things as different. (P25 Site A)*

Some risk assessments were tailored for pregnant or laboring women; however, these were also not perceived as particularly useful. These types of features in the EHR are intended to provide cognitive support by reminding the nurse to assess a particular risk factor at specified intervals to enhance safety. However, they did not account for nuances in the clinical scenario. When questions were answered in a way that escalated the patient's risk level, the nurse was sometimes prompted to respond with certain interventions or manage the alert, and sometimes not prompted to do anything. These risk assessments, though tailored, did not seem to work as intended, as they either fired too early or were too easily silenced. For example, a nurse described the hemorrhage risk assessment as prompting her to initiate interventions that might not be appropriate for a patient's present condition, even if she had a reason for heightened surveillance for hemorrhage. This created a dilemma for the nurse when they had to decide whether to ignore the prompts or go through the motions of responding to alerts and prompts that

were illogical. In this way, certain cognitive support features in the EHR introduced undue complexity by creating extra work that did not enhance or support nurse decision-making.

> *And the sepsis screening, I do it, but I feel like the questions are weird. Because it will say, did you screen, and then what are the abnormal values, and let's say you did find one, fetal tachycardia, and then it says, did you call a sepsis code and if you say no, you might comment about why.[Whether] you say yes or no, it gives you credit for completing it, and it's off your checklist. There's not a hard stop [to respond in a specific way], so I feel like it maybe doesn't force people to [fulfill the purpose of the risk assessment]... they could be a high sepsis alert, but if you just go through the boxes and just get rid of them, it's not going to alert us. It doesn't continue to remind you to do certain things, as long as you do it for that shift it's gone [but over 8-12 hours the situation could change]. (P28 Site B)*

Forcing functions in the EHR. Forcing functions are used in many high-risk industries to enhance safety. They are built-in features or design configurations that prevent errors by requiring that tasks follow a particular sequence, or by forcing the user to take a particular action or evaluate information before proceeding to the next step (Wachter & Gupta, 2018). Nurses in this study encountered challenges deciphering the logic behind forcing functions, which created an obstacle that interfered with the flow and efficiency of their work. They spent time problem-solving issues they did not understand, distracting them from being focused on important aspects of clinical care and impeding their situation awareness. This was particularly problematic for the role of circulating nurse during a cesarean birth, where nurses maintain the sterile field, track the needs of two surgeons, a surgical tech, and an anesthesiologist; monitor blood loss and instrument and sponge counts; assist with medication administration; document critical times and events; and assess the need for additional interventions and personnel. Trouble-shooting documentation issues in the operative record during this time can be particularly hazardous.

> *If you didn't write certain times down somewhere, on your scrubs, on a piece of paper, then it can be a challenge because you have to document certain events for each of the sections. For example, [entries have to fall] between the time you recorded entering and*

> *leaving the operating room. If you try and document outside of those times and don't adjust the time, it blocks you from moving forward. It's the same thing preoperatively. A lot of people still struggle… they can't verify, and then they get frustrated. "Why can't I verify this and go forward?" It's because there's one other place they didn't click... I find it's still painful and that is a place that it affects my global awareness trying to click that much. When you're circulating [your focus needs to be on more important things]. (P26 Site B)*

Consequences: Shifting Responsibility for Managing Information and Cognitive Support from System to Nurse

With the exception of the electronic medication administration record and bar code medication administration, which nurses agreed improved the safety of the medication administration process, nurses found most features in the EHR that theoretically should support their cognitive work to be a hindrance in practice. This was because of the way these features were executed in the EHR systems they used.

Missed opportunities for cognitive support. There were numerous examples of missed opportunities for cognitive support, including lack of structured templates for high-risk assessments, insufficient structure around the organization and flow of required documentation, processes persisting on paper, cumbersome layout of drop-down screens, and undue complexity surrounding high-acuity, low-frequency events.

Structured templates. One of the promises of CDS was the availability of structured templates to guide busy clinicians to complete recommended requirements for a particular condition (ONC, 2018b). Nurses in this study did not always have structured screens that guided and prompted them to conduct high-risk assessments that aligned with hospital policies and specialty standards. For example, there were no structured assessment and documentation screens for the standards-based recommendations for one-, two-, and four-hour checks for a patient on magnesium sulfate for preeclampsia. The system also did not prompt nurses through

the essential steps in an independent double check of a high-risk medication or remind them to complete specific required risk assessments.

For the patient on magnesium sulfate, nurses relied on their memory instead of structured documentation templates to guide assessments at recommended intervals, sometimes toggling in and out of several places in the record to document all of the required assessment elements.

> *A big problem that I see is you have a policy and procedure that says like for a Mag patient, it says every two hours, you're supposed to do this and every four hours do this. Whether it's O2 sat, urine output, or lung sounds. And yet, there's not one template that you can click that will remind you of all of those. So you have to remember, "Okay, what am I supposed to do every two hours? What am I supposed to do every four hours for the Mag patient?" (P11 Site A)*

> *[There aren't screens that prompt you] by disease process. You pretty much have to know that. There's a flowsheet for blood, and when you scan the Mag, it shows up on your I&O sheet, but not for disease processes. There's nothing specific for the patient care or the frequent assessments that accompany this high risk medication. (P17 Site B)*

While no data emerged at site B regarding the independent double check, nurses at site A reported that they did not have a structured screen that prompted them to complete all of the recommended safety checks in the independent double-check process for high-risk medications.

> *For the magnesium, you have to chart that it's labeled, it's double checked, it's infusing, pump settings are correct. There isn't one screen with all those factors on it that matches the policy. There's a place to click magnesium 1 gram, then there's another thing you click that you checked it with another nurse, but you still have to [remember to type in other things]. It would be nice to have a magnesium check that prompted you [to do everything that's required]. (P9 Site A)*

Documentation processes persisted on paper. Certain processes persisted on paper and therefore required that the nurse remember to add that task to their routine. In this case support was missed on two levels: first, there was not a structured screen that guided accurate completion and, second, this task resided outside of the EHR so the nurse was not reminded via the EHR's organizing features.

I've asked why the epidural documentation can't be in the EHR, in the MAR. We're required to sign off every shift on a paper epidural flowsheet. I've forgotten to do it because it's part of this physical chart that we aren't really focusing on anymore. Everything is paperless but we still have this piece of paper. I brought that to the [unit council]…we started doing it, and then I didn't see it on the [electronic] list anymore. I don't know what happened…they said it would have to be standardized in all units. I don't know what they really mean by that….in OR, PACU? Where else do we do epidurals [like we do]? (P10 Site A)

Cumbersome screen configurations. The layout and configuration of drop-down menus and screens were sometimes cumbersome and illogical. These may have made sense technically, but apparently had not been tested by users to verify that the information display aligned with their workflow. For example, pharmacies were listed by site number (e.g. CVS #1300) instead of by location, requiring the nurse to scroll through a list of about 100 pharmacy sites to find the one the patient reported during admission. Issues like this were particularly apparent in participant observations, which were done only at site A. However, nurses at both sites reported struggling with learning the logic of the EHR.

She comments that some of the entries aren't logical and easy to navigate. She shows me the pain medication box [on the labor charting screen] which at the top lists Nubain, Stadol, and Demerol—meds they don't ever use. The one commonly used is Fentanyl, which is toward the bottom of the list and not readily visible. She scrolls down to find it comments that this is frustrating and has brought it up numerous times. (Observation notes - P22 Site A)

A lot of it's just kind of getting used to the way it is, which takes a while sometimes until you can kind of figure out, "Oh, I guess they did it alphabetically." (P29 Site B)

Complexity surrounding high-risk, infrequent events. The execution and documentation of some low-frequency, high-risk events such as giving blood were complicated. Nurses described numerous steps to activate the ordering process, trying to locate a small icon to release the blood from blood bank, using a separate screen from the MAR for the documentation of blood, and again locating a small syringe icon to be able to chart it. This was stressful and

interfered with nurses' situation awareness and their ability to maintain a focus on the patient's immediate and potential future clinical demands.

> *One area with the EHR that I find extremely painful is ordering, obtaining, and charting blood. It's like a detective video game, trying to remember where you chart things. It's such a stressful situation already, it's frustrating to deal with [such a complicated process]……. Meanwhile, you have that extra level of thinking and heightened concern [preparing for what might happen next] "We're giving her this now, what do I need to anticipate in the operating room?" (P26 Site B)*

Reinterpreting and correcting information in the EHR. Labor and delivery nurses in this study managed and tracked information in systems that failed to account for variations in care that were unique to the perinatal patient and had limited functionality for them. Tools and features in the EHR designed to support clinicians' cognitive work and enhance patient safety were ineffective, shifting aspects of information management from the system to the individual nurse. This added to the volume and complexity of nurses' work as they corrected automated functions and reinterpreted or ignored risk assessments and other types of alerts.

> *My perspective of things like fall risk is yeah, there are requirements that the hospital has, and they're trying to do the best they can with meeting them. It's just part of the EHR game that you have to play…. But at the end of the day, you assess your patient yourself to see if they're a fall risk. You don't base it off of a computer anyway. And as far as the labs go, it's the same. You work in OB, so you look at what your norms are supposed to be for your specialty. So I don't care about the alerts that we get. (P26 Site B)*

Missed care. The EHRs used by nurses in this study did not offer dependable features to assist with their process of assembling and maintaining a comprehensive understanding or overview of the patient's status; accurately tracking the patient's fluid volume status; receiving reliable alerts for risk assessments, labs, and medications; and benefitting from organizing features in the EHR. These issues often resulted in missed care and were particularly problematic for nurses working in multiple systems.

> *You don't know that you have new doctor's orders or new lab results or anything [because you're not in that system]. It just happened this last week that new orders were put in on a patient, but nobody knew about the orders. It was an antibiotic order. [The doctor] had come in in the morning, they reviewed the chart, they saw the lab, they ordered an antibiotic and they went about their way. They didn't tell anyone, so no one knew. (P25 Site A)*

Cognitive support features, such as automated IV intake calculations, did not work as intended and often introduced inaccurate information into the patient's record. Instead of helping nurses, they added work since they required the nurse to correct the fluid calculations from their own and sometimes prior shifts. This challenged their ability to track and understand the patient's fluid volume status, which is an important clinical assessment in labor and delivery.

> *When you scan [a bag of IV fluid], it registers the time, and the rate of 125, and the volume of 1,000 mLs—but say she was getting an epidural so they gave her more than 125 an hour. So, when you scan a new bag, it calculates that you're wasting 900, because it's not thinking that 900 went in since you hung it less than an hour ago. So, you have to know enough to go back and change it, and a lot of nurses don't or they're in a hurry, so they think, "Okay, I'm gonna go back later and change it." But they're unable to do that. [So errors are left in the record] (P1 Site A)*

Discussion

Nurses in this study reported problematic use of most available CDS features. The exception was the electronic medication administration record and bar code medication administration, which nurses found helpful and perceived as significant safety enhancements. Other features such as summary or handoff tools, risk assessment screens, alerts and reminders, and disease-specific templates were either not used as intended or were seen as a distraction that created extra work. These tools lacked the specialty-specific support needed to care for laboring women and instead required nurses to track information in other ways that added to their cognitive burden and work routines. More importantly, nurses and patients were not benefitting from the intended decision support and patient safety protections offered by appropriate risk

assessment screens or critical alerts. In some cases, there were missed opportunities for cognitive support, such as with structured templates for assessing a patient on magnesium sulfate, for the independent double-check process for high-risk medications, and with the overall structure of required documentation screens not always containing all of the necessary elements.

Nurses were not always able to override and correct irrelevant alerts and reminders generated from laboratory results, risk assessment screens and the medication administration record. Poorly designed or inappropriate alerts and reminders are commonly reported in EHR literature (Ancker et al., 2017; Howe, Adams, Hettinger, & Ratwani, 2018; Nanji et al., 2017) and can disrupt a clinician's ability to effectively review relevant safety alerts by demanding excessive interaction with the EHR (ONC, 2018b). Based on the realization that clinicians may have contextualized information and medical knowledge about a situation that the computer cannot understand, experts recommend that clinicians have the ability to override computer-generated interventions (ONC, 2016b). Nurses in this study encountered forcing functions and hard stops in the EHR which they were not able to navigate past in order to continue care, which was particularly problematic when documenting during cesarean birth. Given how disruptive these features can be, forcing functions should be reserved for the most extreme situations and some mechanism for clinician autonomy should be built in so that they are not obstructive (ONC, 2016b). Imposing unnecessarily rigid hard stops that impede the user's ability to navigate out of processes or screens can dangerously disrupt clinicians' work (ONC, 2018b).

Participants at one site in this study did not have access to an electronic summary screen, and at the other site the tool was not used to its full potential because it was perceived as too generic. At both sites, nurses primarily used paper summary and handoff tools. This is consistent with other literature where nurses relied on their tailored forms because they were able to

organize and display information in ways that helped them contextualize and synthesize information (Chao, 2016; McLane & Turley, 2012; Staggers et al., 2011; 2012) and configure information in a way that supported and matched their work (Kossman, Bonney, & Kim, 2013). Access to single-patient data summaries that synthesize a patient's information and guide the clinician's attention toward important clinical information is an expectation in contemporary EHRs (HIMSS, 2019; Tcheng et al., 2017). Summary features that are not effectively organized and implemented for a specific care setting can force the clinician to navigate excessive and irrelevant information and fail to locate pertinent data (ONC, 2018b).

A novel finding in this study was the unique support that labor nurses derived from the paper fetal monitoring tracing. Nurses viewed the paper tracing as a cognitive support tool that helped them accurately track maternal and fetal status and responses to interventions during critical events when they were unable to use the EHR. The practice of running a continuous paper tracing was supported at one study site and discouraged at the other. Nurses still used paper to record information during fast paced or emergency situations at the site where use of the paper tracing was discouraged. However, they did not benefit from recording that information on a continuous tracing that tracked their assessments and interventions temporally and, therefore, they could not readily associate those data with the maternal-fetal status reflected on the tracing at a particular point in time. Interestingly, nurses generally reported more challenges with EHR use at the site where use of the paper tracing was discouraged.

Participants in this study regularly interacted with CDS tools that were not intended for pregnant women; therefore, they were tasked with problem solving how to track information and obtain the cognitive support they needed while silencing or managing irrelevant support features in the EHR. Experts recognize that the implementation of a one-size-fits-all EHR in specialty

areas has the potential to generate additional cognitive burdens for clinicians and introduce potentially hazardous conditions (ONC, 2018b). Studies focused on neonatal intensive care (Shade, Kelly, & Hofmann, 2017), pediatric (Gracy, Weisman, Grant, Pruitt, & Brito, 2012; Ratwani et al., 2018), and behavioral health (Cifuentes et al., 2015) have reported problems generated by the implementation of a hospital-wide EHR. This is the first study to report on challenges encountered by labor nurses when working with an EHR system designed for general care.

Limitations

This study sought to explore direct-care labor nurses' experiences of EHR use and did not seek input from system designers or decision-makers; thus, the breadth of experience of all EHR stakeholders was not presented. Nurses worked in community hospital settings and used EHRs with varying degrees of sophistication and interoperability. Nurses working in other settings and with more fully integrated EHRs may have different experiences. While the median age of nurses in this study was slightly younger than the national median, nurses younger than 35 were not represented, and this group may have contributed different perspectives about the EHR. Strengths of this study were that we used an immersive qualitative methodology which allowed for an in-depth exploration of labor nurses experiences. The key themes reported here are consistent with those identified in other settings, which suggests that they may represent the experiences of labor nurses in other hospitals.

Conclusion

Numerous, large-scale, national efforts have been or are currently being directed toward achieving a better understanding of the challenges that clinicians are facing as a result of EHR use and associated CDS features, and on bringing together the necessary stakeholders—

clinicians, vendors, cognitive scientists, and policy makers—to implement effective solutions (ONC, 2018b; Tcheng et al., 2017). There should be ongoing end-user engagement in evaluating the EHR, including ongoing evaluation of CDS tools, documentation processes, and templates (ONC, 2018b), with a greater focus on understanding nurses' needs and experiences. Findings from this study suggest that nurses working in labor and delivery settings face unique challenges surrounding EHR use that have important safety implications. More research is needed in this and other specialty areas to better understand nurses' perspectives and to inform EHR and CDS design that supports nurses' work and cognitive support needs.

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Table 4.1 *Dimensional Matrix of the Central Perspective Working With and Around Ineffective CDS*

Context	Conditions	Processes	Consequences
A One-Size-Fits-All EHR in a Specialty Unit	**Reallocating CDS Customization to the Nurse**	**Labor Nurses Working With and Around Ineffective CDS**	**Shifting Responsibility for Managing Information and Cognitive Support from System to Nurse**
○ EHR structure designed for general care[1] ○ Pregnancy physiology[2]	○ Degree to which the EHR was customized ○ Use of the paper electronic fetal monitoring tracing	○ Working with and around ineffective CDS ▪ Organizing features ▪ Summary or handoff tools ▪ Alerts and reminders ▪ Automated functions in the MAR ▪ Bedside medication verification ▪ Forcing functions in the EHR	○ Missed opportunities for cognitive support ▪ Structured templates missing ▪ Insufficient structure for required documentation. ▪ Documentation processes persisted on paper ▪ Cumbersome drop-down menus ▪ Complexity surrounding high-risk, infrequent events ○ Reinterpreting/correcting information in EHR[3] ▪ Missed care

[1]The structure of EHRs are designed for general care, so CDS features are tailored to the medical-surgical population. In addition, available IT or informatics support is focused on general care
[2]Physiology of pregnancy affects lab values, vital signs, appropriateness of routine medications, etc. Causes CDS features to misfire
[3]Information management shifts from system to nurse, ignore alerts, nurses devise own cognitive support

Table 4.2 *Participant Demographic Characteristics*

Number of Participants	**21**
Median Age (Range)	49 (36-64)
Median Years in Setting (Range)	20 (5-38)
Highest Degree	
• Associates/Diploma	7 (33%)
• Bachelors	10 (48%)
• Masters	4 (19%)
Shift	
• Days	10 (48%)
• PMs	7 (33%)
• Nights	4 (19%)
Role	
• Charge RN/Shift Supervisor/Coordinator	5 (24%)
• Clinical Nurse	16 (76%)
Ethnicity	
• White	17 (80%)
• Asian	1 (5%)
• Black	1 (5%)
• Hispanic/Latino	2 (10%)

Table 4.3 *EHRs Used*

Feature	Site A	Site B
Main EHR	Physician orders and documentation, laboratory and diagnostic tests, medication management, and intake and output documented and managed in this system	All documentation and information management
Electronic fetal monitoring (EFM) system	Admission, labor, delivery, and recovery documentation for vaginal and cesarean birth. Electronic documentation on virtual EFM tracing	Used for EFM tracing only, no documentation in this system
Use of paper EFM tracing	Rare, discouraged	Yes, continuous
Other systems	Separate system used by anesthesiologists in obstetric perioperative area	None
System integration	Pervasive issues with interoperability and transfer of information between the 3 systems	Interface between the two systems facilitated the transfer of vital signs, an estimated fetal heart rate baseline, and calculation of Montevideo units from the fetal monitoring system to the main EHR
Years since current EHR implementation	7 years	3 years

Chapter 5

Summary of Dissertation

The purpose of this dissertation study was to explore labor and delivery nurses' perceptions of how interaction with and use of the EHR affects their cognitive work, with the goal of understanding patient safety implications. Three papers comprised Chapters 2, 3, and 4. Chapter 2 was an integrative review of the literature about the impact of the EHR on nurses' cognitive work. Chapter 3 presented results of a grounded theory analysis that explored labor and delivery nurses' experiences of *configuring care* when using the EHR and how they *integrated the EHR* into their practice. Chapter 4 reported an analysis that focused specifically on labor and delivery nurses' use of cognitive support features in the EHR.

The integrative review in Chapter 2 was a comprehensive search of the literature that focused on 3 concepts: the electronic health record, cognition, and nursing practice and synthesized findings from 18 studies from 5 countries. Five themes identified how nurses and other clinicians used the electronic health record and perceived its impact: 1) forming and maintaining an overview of the patient, 2) the cognitive work of navigating the electronic health record, 3) the use of cognitive tools, 4) forming and maintaining a shared understanding of the patient, and 5) loss of information and professional domain knowledge. Findings indicated that nurses experienced challenges forming and maintaining an overview of the patient, navigating in the EHR, synthesizing scattered and fragmented information from throughout the medical record, and using EHR-generated tools to summarize clinical information. The EHR was perceived as an impediment to contextualizing and synthesizing information, communicating with other professionals, and structuring patient care.

This review also identified important gaps in the literature that this dissertation study sought to address. Few studies have investigated the impact of the EHR on nurses' cognitive work, and most findings reported in the review were incidental findings from studies focused on

clinician perspectives. More importantly, few studies used immersive qualitative methods. When cognitive work is defined using clinical grasp and situation awareness (Benner et al., 1999; 2009; Endsley, 1995) and as part of a complex sociotechnical system (Harrison, Koppel, & Bar-Lev, 2007), immersive methods are required to fully understand how nurses interact with the EHR and to explore safety implications (Blumer, 1969; Lintern, & Motavalli, 2018).

Chapter 3 reported the main findings of this study that explored labor and delivery nurses' experiences using the EHR. The dimension with the most explanatory power described how nurses *configured care when using the EHR,* which was shaped by how the nurse *integrated the EHR* into their practice. This took place in a dynamic, high-acuity, specialty clinical environment while using EHRs that were not designed for pregnant women. Various factors at the individual, group, and situational level facilitated or constrained nurses' ability to integrate the EHR into their care. Nurses saw the quality of their relationship with patients and their families as an integral part of caring for laboring women and felt that interaction with the EHR sometimes threatened this dimension of their work. When nurses were unable to integrate the EHR into care it resulted in numerous consequences that have important safety implications.

Chapter 4 presented an analysis that focused specifically on labor and delivery nurses' use of cognitive support features in the EHR. While other cognitive support features were included, the study focused primarily on labor nurses' use of clinical decision support (CDS). Nurses reported problematic use of most available CDS features. The exception was the electronic medication administration record and bar code medication administration, which nurses perceived as helpful to catch and avoid medication errors. Other features such as summary or handoff tools, risk assessment screens, alerts and reminders, and disease-specific templates were either not used as intended or were seen as a distraction that created extra work.

These tools lacked the specialty-specific support needed to care for laboring women and instead required nurses to track information in other ways that added to their cognitive burden and work routines. More importantly, nurses and patients were not benefitting from the intended decision support and patient safety protections offered by appropriate risk assessment screens or critical alerts. In some cases, there were missed opportunities for cognitive support, such as with structured templates for assessing a patient on magnesium sulfate, for the independent double check process for high-risk medications, and the overall structure of documentation screens not always containing the required elements.

Synthesis

The findings from Chapter 3 aligned closely with those from the integrative review in Chapter 2. In both, nurses experienced challenges forming and maintaining an overview of the patient at the individual and team level and with navigating the volume of available data in the record to find relevant information. Information in templates and the loss of narrative notes made it more difficult to understand the chronology of the clinical situation and grasp the associations and implications of data.

The review of the literature was the first to synthesize the impact of the EHR on nurses' cognitive work, and the study presented in Chapter 3 was the first to report on labor and delivery nurses' experiences of the cognitive support offered by the EHR. While this study extended and confirmed findings from the review, it presented two novel findings. These were the primacy of the nurse-patient relationship as an information source for labor nurses and an integral part of quality care, and that the presentation of fetal heart monitoring information in a house-wide EHR created challenges for nurses' interpretation of fetal and maternal status.

In the review, clinicians looked to each other's clinical reasoning and interpretations when working through their own understanding of a clinical situation and found that locating this type of information in the EHR was difficult. I expected labor nurses to report similar experiences. While all participants identified report or handoff as a key information source, nearly all nurses reported that they relied mostly on *interaction with the patient and family* to complete their understanding of the patient's status.

Nurses were deliberate in their efforts to develop a relationship with their patients and families and viewed this part of their work as essential to quality care. Women also report that the quality of relationships during labor and birth are central to their overall birth experience and their perceptions of safety (Lyndon, Malana, Hedli, Sherman, & Lee, 2018). There is a growing understanding of patients' experience of emotional safety and their overall perceptions of safety, which may have important implications for efforts to improve patient experience (Lyndon, Jacobson, Fagan, Wisner, & Franck, 2014). The findings from this study suggest that nurses sometimes experienced interaction with the EHR and its associated technology as a threat to this dimension of their work.

This is the first study to report on nurses' perceptions of how well the format and structure of information in the EHR supported their ability to interpret fetal heart monitoring information, particularly the ability to quickly evaluate pattern evolution over time. Nurses used different systems at the two study sites, and those who worked in software designed for the electronic fetal monitoring system perceived it more favorably and reported that it supported this aspect of their work. Nurses working in a house-wide EHR that had not been customized for labor and delivery reported difficulty interpreting fetal heart monitoring information documented in this system, particularly the ability to quickly assess changes over time. This meant they often

did not use or view information in this way and instead conducted their own review of the paper tracing. Reviewing the tracing to arrive at one's own interpretation of maternal and fetal status is likely considered routine by most nurses; however, nurses at site A benefitted from the ability to view the evolution of maternal-fetal status in a flowsheet format as well.

No studies have reported on CDS use in inpatient perinatal settings. The overall theme in the analysis in Chapter 4 revolved around the challenges generated from using a one-size-fits-all EHR in a specialty unit. Pregnant women's laboratory values, vital signs, risk factors, and medication safety profiles are different from the general population; thus, CDS features designed to respond to deviations from normal adult laboratory or other physiologic values misfire when applied to pregnant women. This caused nurses to routinely manage or silence irrelevant reminders and alerts and shifted the responsibility for certain aspects of information management and cognitive support expected of the EHR from the system to the nurse.

One of the most interesting findings from this study was the unique support that labor nurses derived from the paper fetal monitoring tracing. Nurses viewed the paper tracing as a cognitive support tool that helped them accurately track maternal and fetal status and responses to interventions during critical events when they were unable to use the EHR. Nurses at both sites reported not using the EHR during high-acuity situations and instead documenting on paper. The practice of running a continuous paper tracing was supported at one study site and discouraged at the other. While nurses still used paper to record information during these times at the site where use of the paper tracing was discouraged, they did not benefit from the structured cognitive support that was provided when recording information on a continuous printout with timestamps. Those nurses who used the paper tracing were able to quickly make notes as they provided care and could readily associate those interventions both temporally and with the

maternal-fetal status reflected on the tracing at that time. More importantly, this supported nurses' situation awareness and ability to focus on the critical event instead of tracking information.

Implications for Clinical Practice

The findings from the review in Chapter 2 and analysis in Chapter 3 suggest that the EHR did not always provide the information needed to support nurses' work. Nurses either sought information from each other or obtained it from interaction with the patient and family when completing their understanding of the patient's clinical status. To this end, the EHRs used by nurses in this study failed them in two essential ways. First, the organization and structure of information in the EHR made it difficult to easily locate and synthesize clinically relevant information. Second, cumbersome workflows and ineffective features required excessive interaction with the EHR to manage, thus hindering nurses' ability to focus their attention toward the people and activities that did provide needed information. To support nurses' work, EHRs should be designed to address both of these things: distilling information and making it easy to find and synthesize, and simplifying EHR-related work so that nurses can focus on interacting with each other and with the patient and family.

Many of the issues identified in these data could be improved by actively engaging end-users and streamlining change processes. Nurses at site B felt they had a pathway to express concerns but change processes were sluggish and complicated. At site A, nurses did not feel there was a clear route to contribute their ideas for improving the system. Continuous end-user input and engagement are recommended as key strategies for improving the safety and usability of EHRs (Office of the National Coordinator for Health IT [ONC], 2016; Tcheng et al., 2017). Nurses in this study spent considerable time managing ineffective CDS features and found them

distracting. Organizations should seriously investigate the efficacy of CDS features in EHRs in labor and delivery using input from end-users and actively improve or remove ineffective tools.

The ease with which nurses integrated the EHR into their practice was shaped by individual, organizational and environmental factors. At the individual level, a nurse's fluency with the EHR and prior experiences affected integration, as did environmental factors such as having to troubleshoot technology and equipment that were not working. These issues could be improved by providing increased access to information technology support that is readily accessible in real time and by more proactive management of devices and equipment by engineering staff. This might include ongoing EHR training or the availability of EHR champions on the unit, and regular equipment and technology checks. The findings from this study also suggest that nurses should be supported in using the paper electronic fetal monitoring tracing if they find this helpful for recording and interpreting information.

Directions for Future Research

There are several areas to direct future research efforts. Exploring nurses' perceptions of the EHR's impact on their cognitive work in settings where the systems are tailored for pregnant women would help to identify which of the issues reported in this study were related to technology in general instead of poorly designed features. Using human factors and sociotechnical systems frameworks, research could focus on understanding what types of EHR design features and data presentation best support how labor nurses retrieve, organize, synthesize, and communicate information; how to integrate narrative notes and evaluate handoff and summary tools specifically for labor and delivery; and how to effectively support clinical grasp and situation awareness. Given that all nurses in this study reported not using the EHR in high-acuity or emergency situations, more research is needed to understand if there are design

features that might support EHR use in these circumstances, or to identify what types of tools or processes outside the EHR are needed to best manage and record information in the interim.

Other salient themes were identified in these data that may be valuable to analyze further and pursue in future studies. These were missed nursing care generated by EHR use; the implications of working in multiple systems with limited or no interoperability; hierarchical issues; the reallocation of work from physicians and others to nurses; and documentation quality.

Conclusion

Many of the promises of the EHR and associated safety and quality improvements hinged on expanded access to information and enhanced clinical decision support (Institute of Medicine [IOM], 2003). Taken together, the results of the three papers presented in this dissertation suggest that neither of these promises have been realized. Using a human factors and sociotechnical systems framework and an immersive qualitative methodology enabled us to explore the EHR as part of a complex system that varied across the two sites. This dissertation filled an important gap in the literature as the first study to report on the EHR's effect on labor and delivery nurses' cognitive work and their use of CDS.

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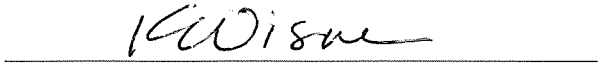

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